


HYDRAULIC VULNERABILITY MANUAL

February 2022

This page intentionally left blank

Hydraulic Vulnerability Manual

New York State Department of Transportation

Office of Structures – Main Office Hydraulic Engineering Unit

February 2022

Key for Revisions:
The 2022 Hydraulic Vulnerability Manual (HVM) supersedes the May 1992 HVM and all revisions.

This page intentionally left blank

FOREWORD

In order to serve, protect and preserve the health, safety and welfare of the public, New York State requires the comprehensive inspection of all bridges that are publicly owned, operated, or maintained as defined in section 230 of the Highway Law, and that also carry public highway traffic.

This document replaces the *Hydraulic Vulnerability Manual – 1992* published in 1992 by the New York State Department of Transportation.

Office of Structures.
James H. Flynn, P.E.

DEPUTY CHIEF ENGINEER (STRUCTURES)

This page intentionally left blank

2022 EDITION
ACKNOWLEDGMENTS

This edition of the Hydraulic Vulnerability Manual is the result of an ongoing, collective effort of many people in the NYSDOT hydraulic community. The Main Office Hydraulic Unit along with several Regional Hydraulic Engineers developed this edition based upon current Federal and State hydraulic policy, standards, manuals, and documents.

Changes were also developed based on data and observations collected at bridges crossing water over the past 30 years. Final edits are provided to achieve uniformity in presentation, technical content and writing style. Also fundamental in the writing and revision of this manual is the addition of many sketches, maps, screen shots, and photographs to assist in how to rate hydraulic variables when observing them in the field or calculating them in the office.

Thanks to the individuals who provided comments and feedback throughout the development process. Special thanks to the following individuals for their direct involvement regarding technical decisions and writing of this edition of the manual:

Lallman Rambali, P.E. Region 5
David Hensberry, E.I.T. Region 9
Richard Frusciante, P.E. Region 8
Louis Hutter, P.E. Region 1
Derek Intschert, P.E. Main Office Hydraulics Unit Supervisor

Editor and Coordinator
Larry J. Tolfa, P.E. Main Office Hydraulic Unit Supervisor (Retired)

Table of Contents

HYDRAULIC VULNERABILITY

SECTION 1 GENERAL

1.1 Purpose

The purpose of this document is to describe in detail the New York State Department of Transportation (NYSDOT) Hydraulic Vulnerability program. The goal of this program is to reduce the vulnerability of state and local bridges and their immediate approaches to failures caused by scour. As a result of these efforts, bridges prone to scour damage are identified and a Plan of Action (POA) is implemented to reduce the hazard of Hydraulic Vulnerability following federal mandates.

The goals of the Hydraulic Vulnerability program are accomplished through a series of assessments and evaluation steps which results in a Hydraulic Vulnerability Rating for a structure. The Vulnerability Rating uses the Likelihood and the Consequences of a failure to determine a failure risk and the urgency of the corrective action needed. The rating is used in conjunction with Vulnerability Ratings from other failure modes to establish priorities for taking actions on a bridge.

The different segments of the Hydraulic Vulnerability program are summarized in Section 1.2. More detailed discussions can be found in subsequent sections.

1.2 Summary

The purpose of this section is to provide an outline of the Hydraulic Vulnerability program. It briefly describes the major steps included in the program and the products resulting from the completion of each of these steps. It does not include specific details on the methodology for accomplishing the different assessment steps and related tasks. Additional details can be found in subsequent sections of this document and in other documents in the references provided.

Figure 1.1 shows the overall Hydraulic Vulnerability program which consists of an assessment, an evaluation, and an implementation phase. Descriptions of each of these different phases follow.

Vulnerability Assessment – The Vulnerability Assessment process is based on the screening and evaluation procedures recommended by the Bridge Safety Assurance Task Force (BSATF). Now superseded, the BSATF report is available in the archive library in the Main Office. However, the BSATF process was comprised of a screening, a classifying, and a rating step. The screening process is now complete and is no longer performed. In addition, a POA may be included in the Vulnerability Assessment process and is described in detail in Section 5. Figure 1.2 & 1.3 shows an overview of each of the steps in the process and is briefly described below. A detailed description of each of these steps can be found in the subsequent sections of this manual.

The three steps in the Vulnerability Assessment process are intended to be progressed sequentially on a priority basis and each step provides an increasing understanding of the Hydraulic Vulnerability of a bridge. Since the screening step is complete, only the classifying and rating steps are needed for the Hydraulic Vulnerability Assessment. Bridges with higher Hydraulic Vulnerabilities should be progressed through these steps first, to focus on developing appropriate actions that should be taken on the most critical bridges in the shortest amount of time.

Completing the Vulnerability Assessment process requires a review of construction plans, inspection reports, BIN folders and other related documentation. Site visits may also be required to confirm information and gather additional data. Many of the decisions in the Vulnerability Assessment process require judgments to be made about the hydraulic characteristics and performance of a bridge, and it is important that these decisions are made by an engineer specially trained in bridge hydraulic principles.

Screening – The screening step was completed for all existing NYSDOT bridges and is not used for new bridges or revised HVA's. All reevaluated HVA's are generally triggered through inspections or field observations by the Bridge Inspector. However, it is possible that an HVA would be requested by someone other than the Bridge Inspector. Including, but not limited to, Maintenance Staff, Local Officials, or the Regional Hydraulic Engineer. The screening step consisted of an Inventory Screen and a more refined Susceptibility Screen. The primary goal of the screening step was to set priorities for progressing bridges to the classifying step.

The Inventory Screen was a preliminary screening procedure designed to evaluate all NYSDOT bridges using the information contained in the Bridge Inventory and Inspection System (BIIS) data files. This information is now located in Bridge Data Information System (BDIS) within the Enterprise Asset Management System (EAM). Structures which were not over water were identified and removed from the remaining steps in the Hydraulic Vulnerability Assessment process. Bridges which did cross over water were screened based on the structural foundation information contained in the BIIS database. This screening provided a relative assessment of the Hydraulic Vulnerability of a bridge and was used to set the order for progressing bridges to the Susceptibility Screening step.

The Susceptibility Screening step was used to place bridges into one of four Susceptibility Groups. These groups imply a relative susceptibility to damage from scour and were used to determine the order in which bridges were progressed to the classifying step.

For implementation purposes, the Susceptibility Screening process was divided into two phases.

In the first phase, structures with low susceptibility to damage from scour were identified and these bridges were placed in the fourth Susceptibility Group. For example, bridges which cross over water, but had no substructure units founded in the floodplain, or bridges which had piers and abutments founded on sound non-erodible rock foundations and were clearly not susceptible to damage from scour. These bridges were identified and placed in the fourth Group.

In the second phase, bridges were placed into a Susceptibility Group based on the susceptibility of the pier and abutment foundation configurations. For example, bridges with long steel or concrete piles were placed in the third Susceptibility Group; bridges founded on short piles or timber piles were placed in the second Susceptibility Group; and bridges founded on spread footings on earth or bridges with unknown foundations were placed in the first Susceptibility Group.

At the completion of the Susceptibility Screening step, bridges in Susceptibility Group 1 were progressed to the classifying step first followed by Groups 2, 3 and 4 respectively.

Classifying – The purpose of the classifying step is to evaluate the Hydraulic Vulnerability of a structure to scour damage based on its geologic, hydraulic, and riverine conditions. The product of this step is a Classification Score which serves two purposes. First, it quantifies the potential Hydraulic Vulnerability of a structure to scour damage relative to other bridges in the classifying process. Second, the Classification Score is used to place a structure into a HIGH, MEDIUM, or LOW Hydraulic Vulnerability Classification. The Hydraulic Vulnerability Classes describe the relative potential a structure has for failure due to scour. These classes are used in determining the Hydraulic Vulnerability Rating for a structure and are also used in deciding whether a structure should have a POA.

A field evaluation may be required to complete the Hydraulic Vulnerability Assessment (HVA) classifying steps. However, in instances when enough information is available (such as Record Plans, Scour Calculations, Hydraulic Data Tables and Historical Records) for the engineer to complete the HVA, a field trip is not required. Only an engineer trained in hydraulic engineering principles should perform these evaluations.

During the field inspections, the evaluating engineer should look for potentially catastrophic conditions which could lead to a sudden collapse of the bridge. If such conditions are observed, then appropriate interim protective countermeasures can be recommended to safeguard the bridge against a failure until a more detailed evaluation and remediation plan is developed.

For implementation purposes, the classifying process is divided into two sections, General Hydraulic Assessment and Foundation Assessment. In each section, specific parameters are examined, and a value is assigned to describe the existing conditions with more hydraulically vulnerable conditions receiving higher values. In the Foundation Assessment section, all the substructure units including abutments, piers and culverts are evaluated. However, only the most critical substructure unit is used to determine the Classification Score for this section. Adding the scores from the General Hydraulic Assessment section and Foundation Assessment section results in a final Classification Score for the structure with the highest score representing the most hydraulically vulnerable bridge. The Classification Scores are then used to determine the appropriate Hydraulic Vulnerability Class.

Rating – The purpose of the Vulnerability Rating step is to provide a uniform measure of a structure’s Hydraulic Vulnerability to failure based on the consequences of a failure and the Hydraulic Vulnerability of the bridge to failure.

The Vulnerability Rating is determined using the results of the classifying process, and when available, the results of a hydraulic analysis, combined with an evaluation of the consequences of a failure. The actual Vulnerability Rating is determined in a manner similar to the classifying process in that scores are assigned to evaluate the likelihood and the consequence of a failure and then these rating scores are added together to determine the Vulnerability Rating.

Plan of Action - A Plan of Action shall be developed for all scour critical bridges. Generally, these are bridges with a Federal Highway Administration (FHWA) National Bridge Inventory (NBI) Item 113 less than 4, or equal to 7 or U. Although Code 7 and U are not considered Scour Critical by Federal Highway Administration (FHWA), NYSDOT considers them as such and requires a Plan of Action. The Plan of Action for an individual bridge contains a schedule for the timely implementation of a specific plan for the bridge. Some things to consider when developing the POA should include scour countermeasures, interim Flood-Watch and/or Post-Flood Inspections to monitor the bridge’s performance. In extreme cases, closing the bridge may be the only option until repairs and/or replacement can be completed.

Whenever a FHWA NBI 113 Item of 2 or below is assigned, the rating factor for NBI Item 60 (Substructure) shall match and other affected items (i.e., load ratings, superstructure rating) should be revised to be consistent with the severity of observed scour and resultant damage to the bridge.

Evaluation – Hydraulic Analysis – For the Hydraulic Vulnerability program, the evaluation phase largely consists of a detailed hydraulic analysis of a bridge. The purpose of a detailed hydraulic analysis is to provide a quantitative assessment of the performance of an existing bridge in comparison to current hydraulic design requirements. The results of this analysis will be used in a structural integrity evaluation (S.I.E.)[1] to determine the stability of a bridge against scour. The analysis is also necessary to design hydraulic improvements and scour protection countermeasures at a bridge and the results can supplement and refine the data used in the classifying and rating procedures.

Implementation – Protective Countermeasures – Protective Countermeasures are features installed at a bridge site to make the bridge less hydraulically vulnerable to damage from scour. These countermeasures are applicable as both an interim response to a scour problem and in response to an S.I.E. of a bridge.

The most commonly used countermeasures are riprap or stone filling, installed at an abutment, pier or culvert. Some of the other available methods include constructing guide banks, rock vanes or spur-dikes to protect the abutments, improving the channel alignment through the bridge to lessen the potential depths of scour. Installing sills, rock riffles, check dams or drop structures can also help stabilize the channel and strengthen the existing foundations. Protective Countermeasures can help reduce the Hydraulic Vulnerability of the bridge if installed properly.

---

[1]Structural Integrity Evaluation (S.I.E.) – A Structural Integrity Evaluation as defined by the Uniform Code of Bridge Inspection is a detailed engineering evaluation which covers all aspects of the bridge's structural condition and integrity as well as present the future needs to preserve or upgrade the safety and serviceability of the bridge. The evaluation covers all vulnerability factors and failure modes and is required by the Uniform Code of Bridge Inspection for a bridge which has a high vulnerability to a structural failure.

Figure 1.1

HYDRAULIC VULNERABILITY PROGRAM

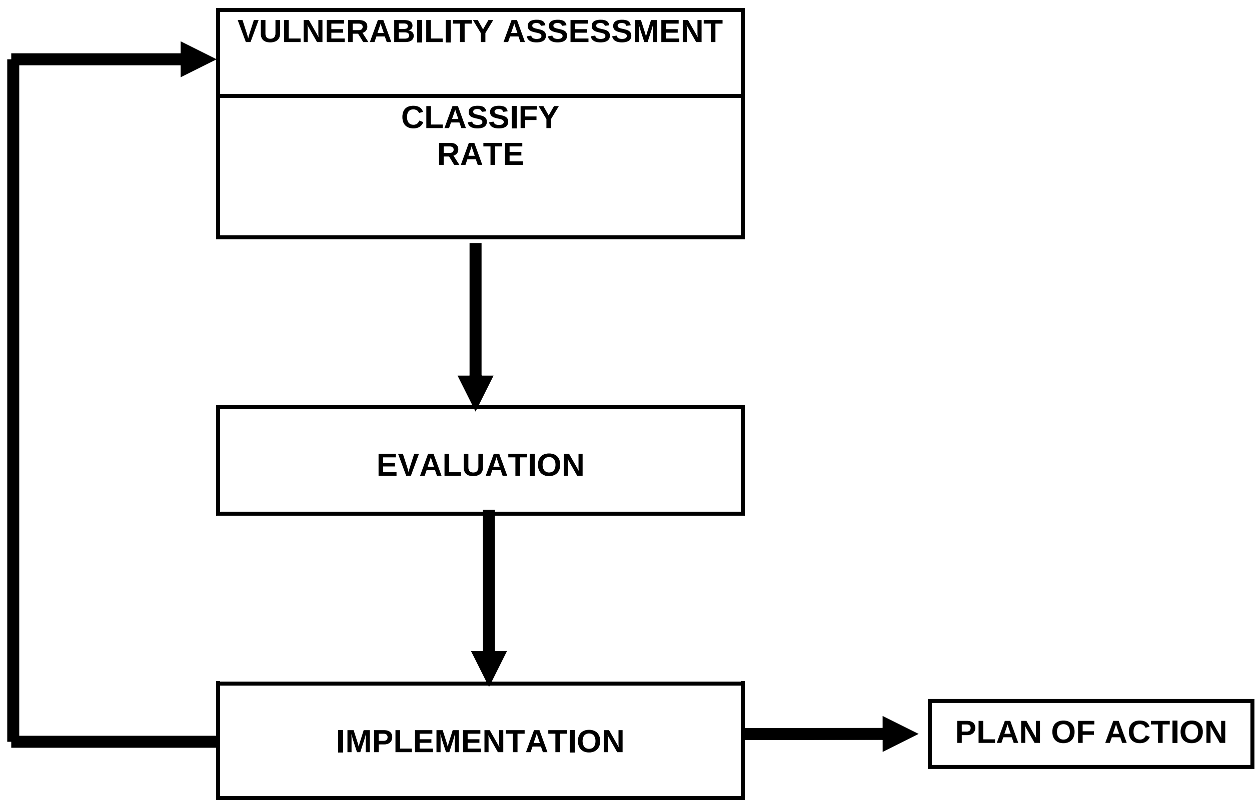


Figure 1.2

HYDRAULIC VULNERABILITY ASSESSMENT PROGRAM

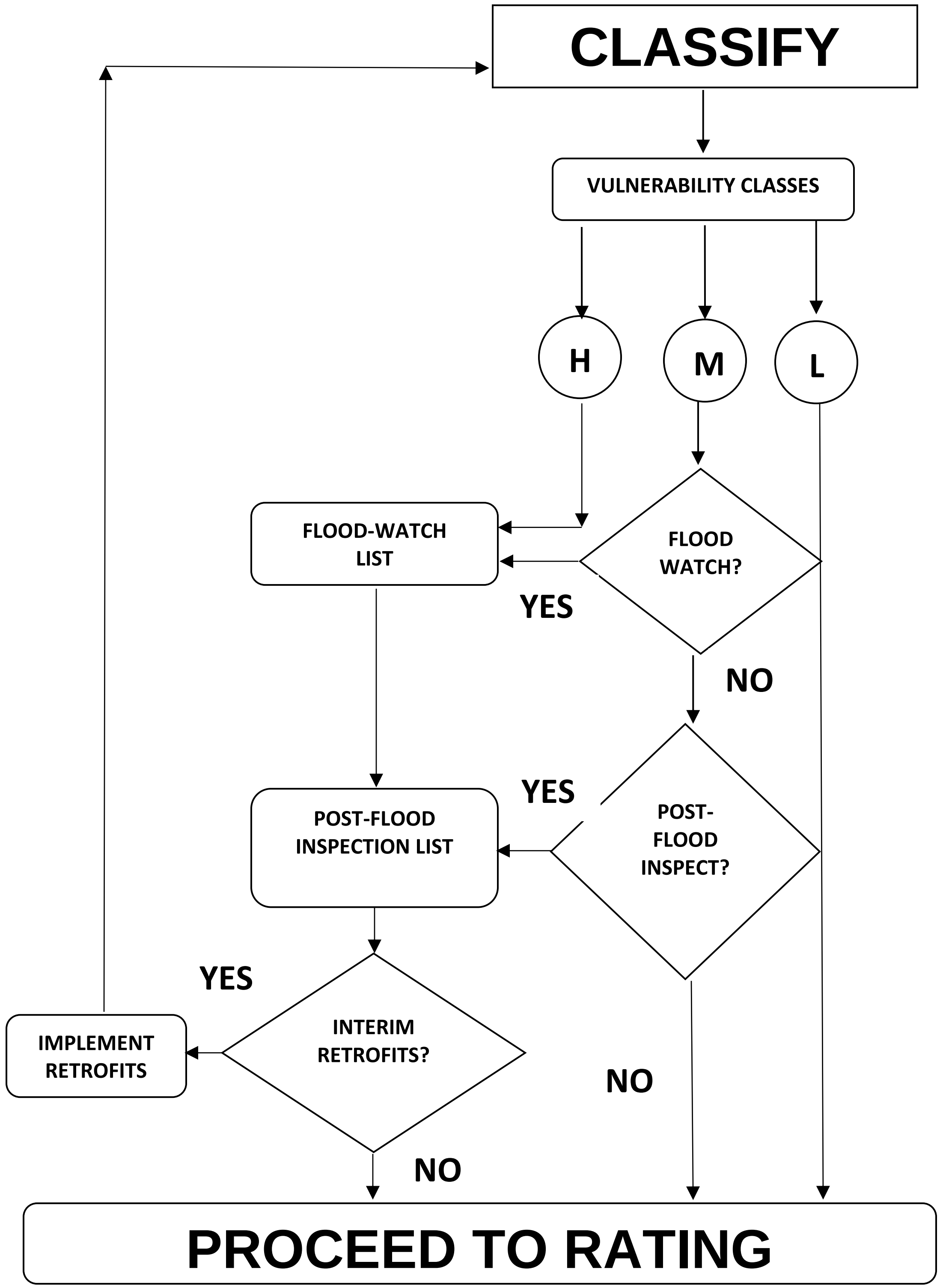
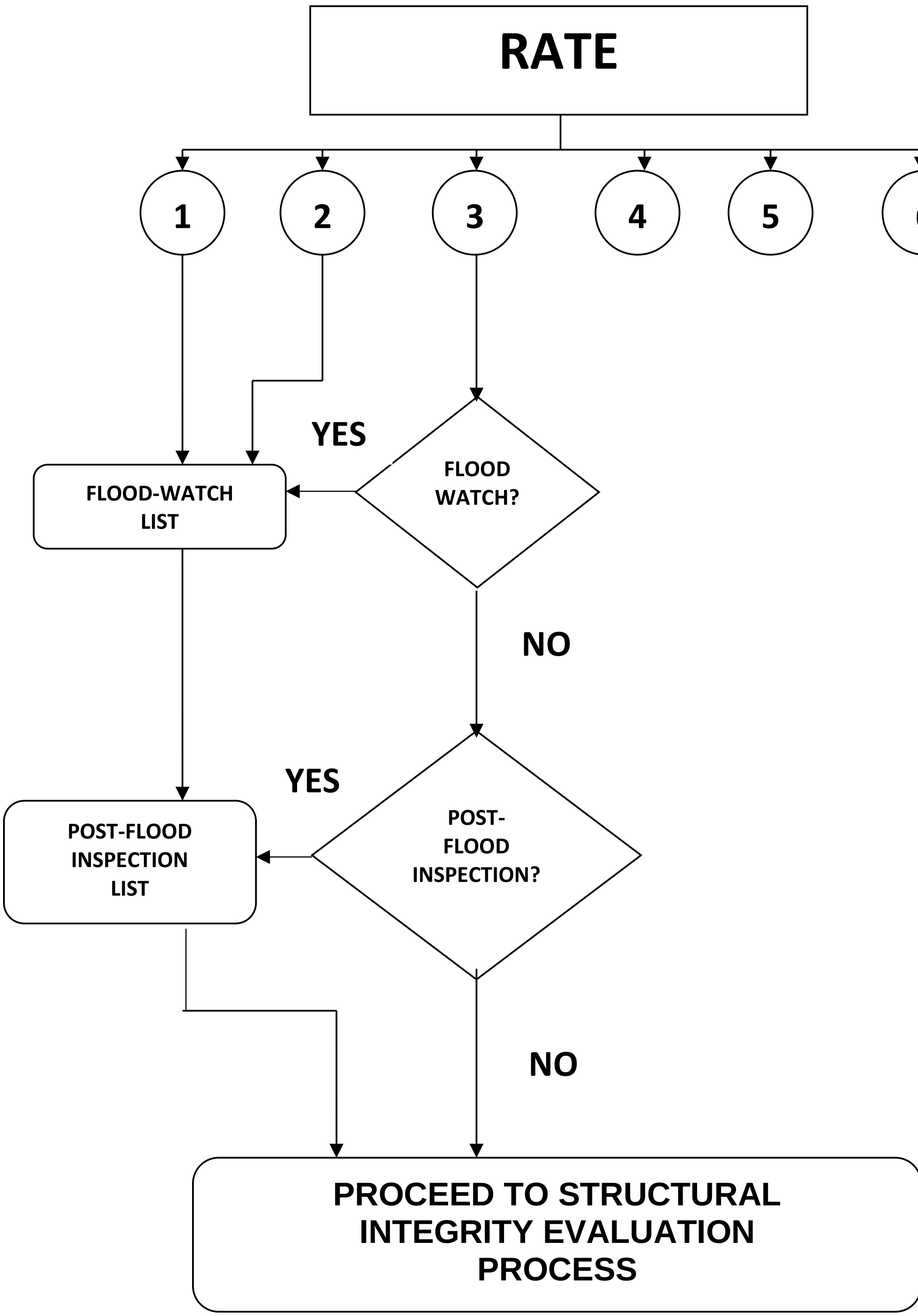


Figure 1.3

HYDRAULIC VULNERABILITY ASSESSMENT PROGRAM



SECTION 2 SCREENING

2.1 Hydraulic Vulnerability Manual

During the initiation of the Hydraulic Vulnerability program, a screening process was developed to prioritize the order in which all bridges would be classified. The screening process was divided into an initial Inventory Screen then a more refined Susceptibility Screen. The Inventory Screen was a preliminary procedure to evaluate all NYSDOT bridges using data that was contained in the Bridge Inventory and Inspection System (BIIS). This database is obsolete, and all bridge data is now contained in the Bridge Data Information System (BDIS) within the Enterprise Asset Management System (EAM).

The preliminary screen was able to identify all bridges that did not cross over water and remove them from the Hydraulic Vulnerability assessment process. Bridges that did cross over water were then screened based on the substructure foundation information contained in BIIS. This Susceptibility Screening step provided an assessment of the Hydraulic Vulnerability of a bridge and was used to prioritize the order of progressing each bridge through the Susceptibility Screening step by placing the bridges into four Groups. Bridges placed in Group 1 had the most susceptibility and Group 4 the least. Group 1 was then classified first, followed by Groups 2, 3 and 4. Examples of bridges in Group 1 were bridges with foundations on earth and no piles. Bridges with short piles or timber piles were placed in Group 2. Bridges with long steel or concrete piles were placed into Group 3. Group 4 contained bridges placed on sound bedrock determined by the Geotechnical Unit or substructures not located in the floodplain. Sound bedrock is determined to erode over centuries and not years. Bridges over lakes or nonmoving water were also placed in Group 4.

The screening process was used to categorize the most susceptible bridges first and least susceptible last. The screening process has been complete for many years and is now not used in the Hydraulic Vulnerability determination. The Hydraulic Vulnerability is determined by the classification scores determined in Section 3. Section 3 evaluates the Hydraulic Vulnerability of a bridge to scour damage. Proceed to Section 3 to determine the Hydraulic Vulnerability score when reevaluating bridges based on changes at the site, as determined during bridge inspections and confirmed by the Regional Hydraulic Engineer or when a new or replacement bridge is constructed.

SECTION 3 CLASSIFYING

3.1 General

The purpose of the **Classifying** step is to evaluate the vulnerability of a structure to scour damage based on geologic, hydraulic, and riverine conditions. The product of this step is a classification score which serves two purposes: first, it quantifies the potential vulnerability of a structure to scour damage relative to other bridges in the classifying process; and second, the classification score is used to place a structure into a High, Medium or Low Hydraulic Vulnerability Class.

The Hydraulic Vulnerability Classes are defined in Table 3.1.1. These classes describe the relative potential a structure has for failure due to scour or other hydraulic forces. They are also used in determining the Hydraulic Vulnerability Rating for a structure and in deciding whether a structure should be placed on the Flood-Watch List with a Bridge Flood Warning Action Plan (Appendix E), and Post-Flood Inspection List or both.

The procedures used in the original classifying process have been adapted from the assessment procedures recommended in the Bridge Safety Assurance Task Force (BSATF) Report. The process in the BSATF Report was designed to provide a degree of uniformity between the results of different evaluating engineers and to assure that all the factors which affect scour are considered. The procedures are not, however, intended to exclude the judgment of a trained engineer. Flexibility exists which allows the evaluating engineer to use judgment and to account for factors which are pertinent and not covered in the detailed procedures. The BSATF Report can be used as a reference but is now superseded by this manual.

Form 3.2 – (General Assessment) shows an outline of the classifying process, which is then combined with one of the following: Foundation Assessment – abutment (Form 3.3.1) or pier(s) (Form 3.3.2) or culvert (Form 3.4). After completing both the General and Foundation Assessments, Form 4.1 will be used to complete the Hydraulic Vulnerability Assessment.

In each section, specific parameters are examined, and a value is assigned to describe the existing conditions, with more vulnerable conditions receiving higher values. A range of values is provided in many cases to allow the engineer discretion in evaluating the observed conditions. In addition, if there are conditions at a bridge which are not covered by the assessment parameters but have a significant effect on the Hydraulic Vulnerability of the bridge, the engineer should assign classifying values which represent a similar vulnerability. Any changes which are made should be completely documented for future reference.

The final classification score is determined by adding the score from the General Hydraulic Assessment section to either Foundation Assessment score or Culvert Assessment score. The Foundation Assessment score is taken as the higher of the abutment or the pier(s) Assessment score. Only the most critical foundation score is used for the Foundation Assessment score; however, all the substructure units on a bridge should be evaluated to determine the most critical foundation.

HYDRAULIC VULNERABILITY CLASSES

HIGH: Conditions exist on the structure and its approaches, or in the stream, which create an unacceptable potential for failure due to scour or other hydraulic forces. Unacceptable implies a risk clearly greater than what is consistent with standard design practice and the occurrence of a single intermediate or large flood which could result in a failure (See Figure 3.1.1). These bridges would be candidates for scour retrofits on a priority basis or on a short-term programmed basis and would have the highest priority for detailed hydraulic analysis. Until an action has been taken and the bridge can be reclassified in a lower Vulnerability Class, a Plan of Action (POA) shall be developed for these bridges.

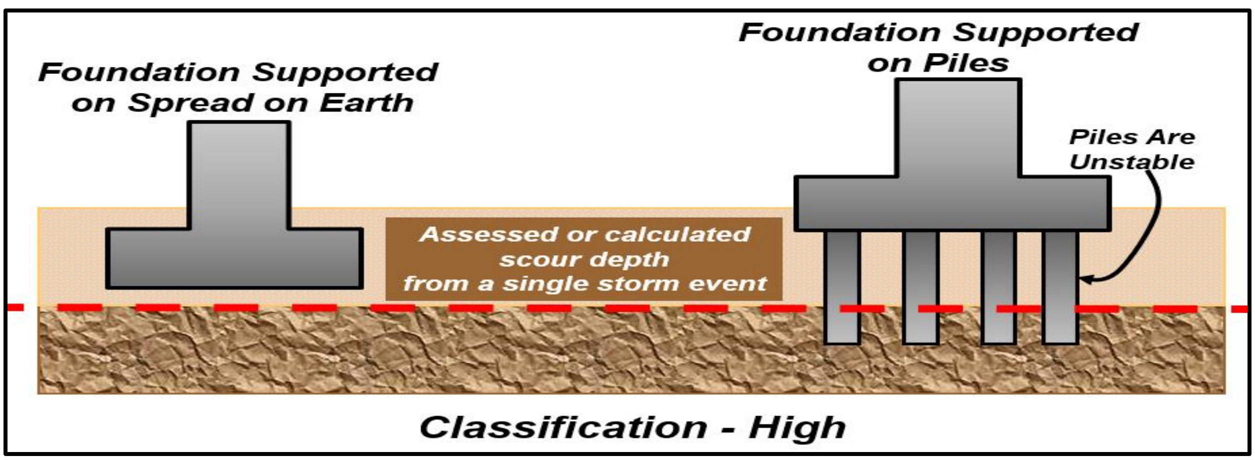


Figure 3.1.1 High Classification Example

MEDIUM: Conditions exist on the structure and its approaches, or in the stream, which create a recognizable potential for failure due to flooding. The risk of failure due to a single design flood or a historic flood is slight, but it is likely that repetitive floods of these magnitudes will result in a failure (See Figure 3.1.2). These bridges would be candidates for scour protection retrofits on a programmed basis. A detailed hydraulic analysis is recommended for these structures and inclusion on the Flood-Watch List should be considered. Bridges in this category may also be candidates for a Post-Flood Inspection List. A Plan of Action (POA) can be developed for these bridges based on recommendations of the Regional Hydraulics Engineer (RHE).

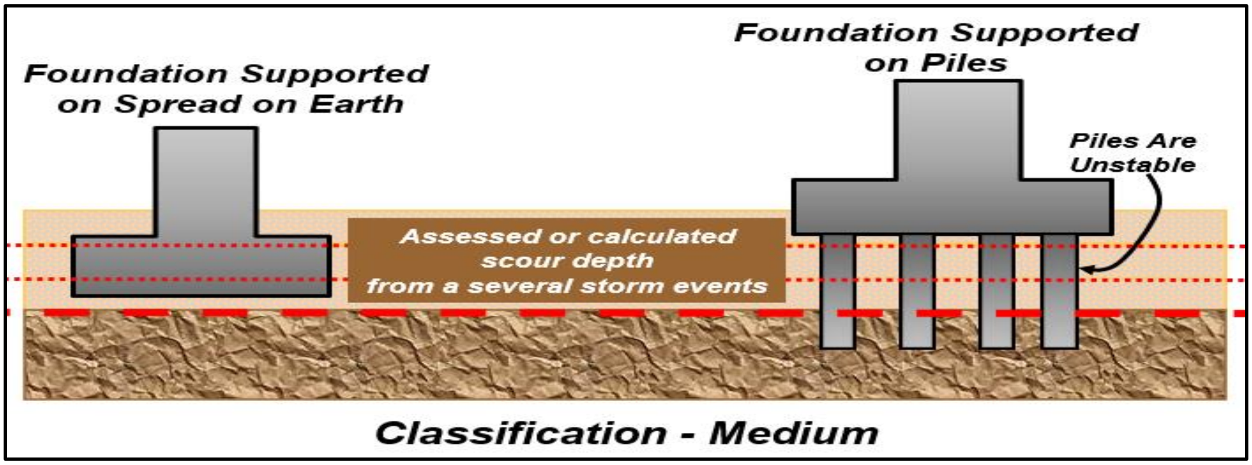


Figure 3.1.2 Medium Classification Example

LOW: Conditions exist on the structure or in the stream, which have little potential for failure due to flooding. There is no risk of failure due to a single design or historical flood and only a remote chance of failure due to an extreme flood. Scour protection retrofits are not required for bridges in this category but scour conditions should be checked as part of general bridge inspections and after major floods. These structures should have the lowest priority for receiving a hydraulic analysis and do not need to be placed on the Flood-Watch List. Inclusion on a Post-Flood Inspection List may be considered for some structures in this category (See Figure 3.1.3).

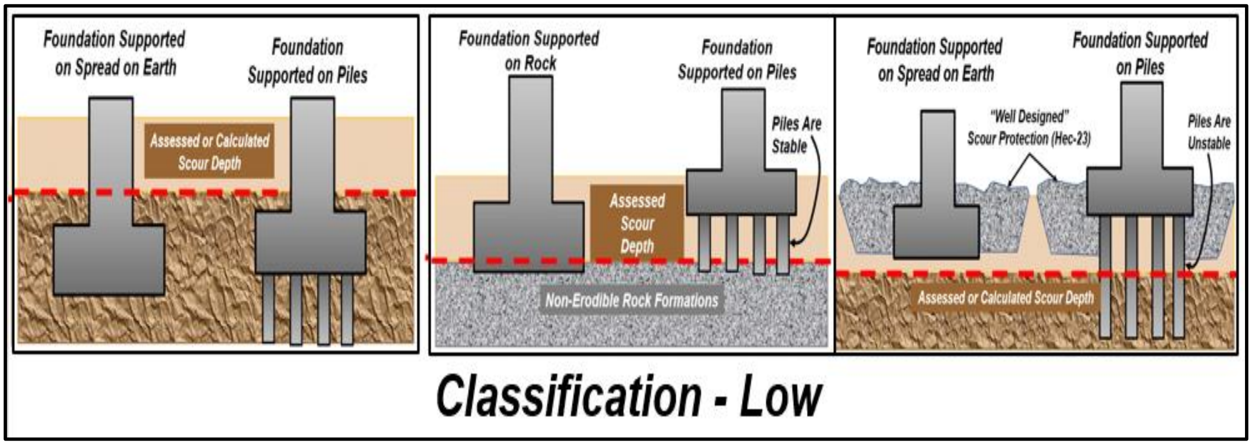


Figure 3.1.3 Low Classification Example

The Foundation Assessment procedures use the accepted conventions for hydraulic investigations to reference the orientation of a structure. Specifically, abutments shall be referred as left and right when looking downstream at the bridge. Pier(s), culverts, and spans shall be numbered from left to right in reference to the abutments. These orientation conventions differ from those used in Bridge Inspection and the relationship between Beginning and End Abutments and span and pier numbers should be noted at the start of the assessment process.

At the completion of the classifying process, bridges are placed into a Hydraulic Vulnerability Class on the basis of the ranges of classifying scores shown in Table 3.1.1.

Table 3.1.1. Vulnerability Classes

Classification Scores

CLASSIFICATION SCORE	VULNERABILITY CLASS
>35	HIGH
20 – 40	MEDIUM
< 25	LOW

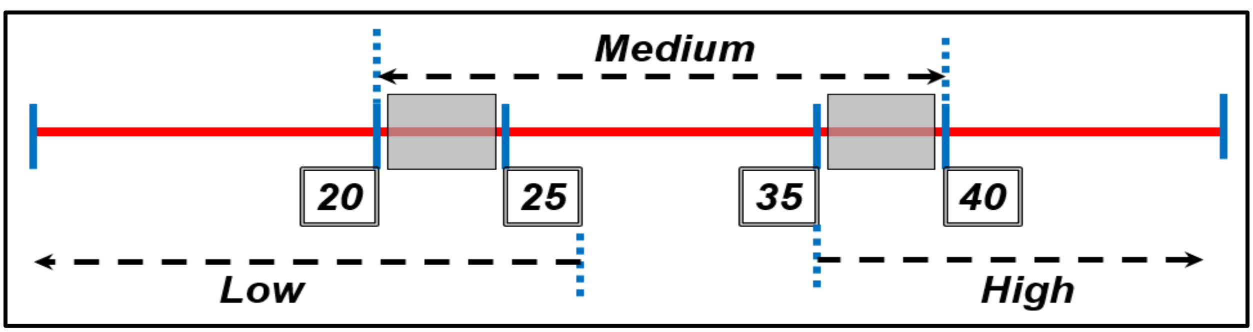


Figure 3.1.4 Overlapping of Classification Scores

Overlapping ranges (Figure 3.1.4) are used to provide the evaluator with some discretion in assigning a Vulnerability Class. The Vulnerability Class coupled with the Classification Score determine the order in which structures should be progressed for the bridge rehab/replacement program.

<u>A field evaluation of the bridge is essential for completing the classifying step.</u> It is important that the evaluations be performed by an engineer specially trained in bridge hydraulic principles, as they require judgments to be made about the hydraulic characteristics of a bridge and stream. It is equally important that all the parameters in the process are addressed, and the evaluating engineer should try to obtain all the necessary data to complete these evaluations.

An ancillary function of the classifying step is to identify any bridges that have potentially catastrophic conditions and to recommend interim scour protection to safeguard against a failure. During the field evaluation, the engineer should look for potentially catastrophic conditions which could lead to a sudden collapse of the structure. If any potentially catastrophic conditions are observed, appropriate interim protective measures should be recommended to safeguard against a failure until a more detailed evaluation and remediation plan can be developed. These recommended countermeasures should be noted on the bottom of the summary sheet (Form 3.1) and the Regional Structures Management Engineer (RSME), or local owner should be notified to assure that these measures are implemented. If the conditions at the bridge warrant it, bridge flagging procedures should also be used.

The countermeasures recommended at this point are intended to be interim fixes aimed at protecting the bridge until more permanent remedial measures can be designed and constructed. Typically, these interim countermeasures will consist of heavy stone fill placed around an abutment or pier, or culverts. However, other measures such as temporary spur-dikes or permanent measures such as sheet pile walls or cofferdams may also be applicable.

In assessing the potential for catastrophic failures, both the conditions at the bridge and the flood characteristics of the stream should be looked at.

The recommended protective countermeasures should not be considered in the classifying process until they have actually been installed. The classifying process should be continued, and the bridge evaluated, considering only the existing conditions. Once the recommended fixes are installed, the bridge can be re-evaluated.

A detailed discussion of each of the sections in the classifying process follows.

3.2 General Hydraulic Assessment

Form 3.2 shows the General Hydraulics Assessment classifying process. This form should also be used to document this section of the classifying process.

This evaluates the vulnerability of a structure to damage from hydraulic forces based on its geologic, hydraulic and riverine conditions. One of the key parameters that influences scour at bridges is *SHEAR STRESS which* is the shear force per unit area exerted on the channel boundary by flowing water.

$$\tau = K_b \gamma R S_f$$

Where: τ = Bed Shear Stress
K_b = Bend Coefficient
γ = Unit Weight of Water
R = Hydraulic Depth ≈ Water Depth
S_f = Slope of Energy Grade ≈ Streambed Slope

The parameters which are included in this section have a general impact on the potential scour depth at a bridge.

a. *Channel Bottom*
b. *Channel Configuration*
c. *Ice/Debris Problems*
d. *Near River Confluence*
e. *Affected by Backwater*
f. *Existing/Historic Scour Depth*
g. *Historic Maximum Flood Depth*
h. *Adequate Opening*
i. *Overflow Relief Available*

Also included is a question on the type of streambed material. This parameter is included primarily to record observed conditions and helps in assessing channel slopes and stream power. No classifying scores are assigned for this parameter.

Each classifying parameter are discussed below, and the associated scores are found on Form 3.2.

Streambed Material: The size of the sediment observed on the streambed can have some indication of the stream power a stream has during storm events. For example, a streambed with large cobbles has more stream power and a steeper slope then a stream with very fine gravel (See Figure 3.2.1). Streams with higher stream power can develop larger scour depths at bridge foundations.

Figure 3.2.1 Streambed Material & Stream Power

a. River Slope

A steep stream flows faster (higher velocity) and is expected to experience more severe scour than one with a medium or flat slope. The stream slope categories are defined as follows:

1. Mild S<0.0001 ft/ft
2. Mild-Medium 0.0001<s<0.0.001 ft/ft
3. Medium 0.001<s<0.005 ft/ft
4. Medium-Steep 0.005<s<0.02 ft/ft
5. Steep =>0.02 ft/ft

Classification scores are assigned for each category to reflect the relative effect on scour potential. A range is provided in the steep category to allow the engineer to increase the score for very steep conditions.

Table 3.2.1 River Slope (S) Classification Scores

RIVER SLOPE (ft/ft) = s				
Mild	Mild-Medium	Medium	Medium-Steep	Steep
<=0.0001	0.0001<s<0.0.001	0.001<s<0.005	0.005<s<0.02	=>0.02
0	1	2	3	4

The reach of the stream channel to be considered when determining the slope (s) should be approximately 500 to 1,000 feet upstream and downstream of the bridge (See Figure 3.2.2) and the slope (s) should reflect the energy grade line of the stream through the bridge for the 100-year flood.

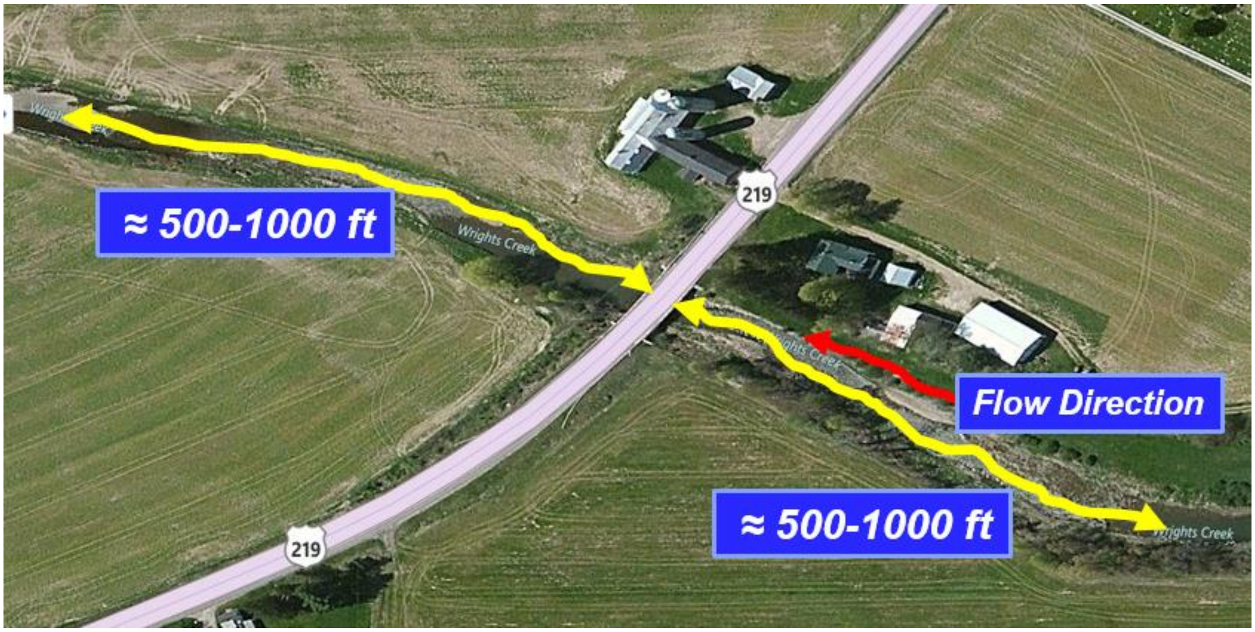


Figure 3.2.2 Location for Determining Channel Slope

Localized changes in the stream slope, caused by low dams or scour holes, should be evaluated by the engineer to determine the effect on flood flows and velocities. In general, these changes can be neglected because the higher flows during a flood will tend to eliminate their impact. For instance, a scour hole upstream of a bridge will tend to flatten the channel slope if considered locally. During a flood, however, the higher flows will pass over the hole and it will have no impact on the overall flood depths or velocities. However, if the engineer considers localized changes in slope to be significant enough to control the flood flow velocities, then flood flow velocities should be used.

The river slope can be determined from the stream profile data in the vicinity of the bridge, from any of the following sources:

1. Existing hydraulic models, if available
2. FEMA Flood Insurance Studies - stream and water surface profiles
3. Profile plot of streams from USGS StreamStats Program
4. Profile plot of streams from Watershed Modelling Systems (WMS)
5. USGS Contour Maps

U.S.G.S. contour maps should only be used as a last resort. The ten or twenty-foot contour intervals on these maps may not reflect significant changes in a river's slope, and therefore, may not accurately represent the slope in the vicinity of the bridge. If U.S.G.S. maps are used, the engineer should verify that the slopes reflect actual current conditions.

Existing Hydraulic Models

The slope of streambed can be obtained from existing hydraulic models such as Hydraulic Engineering Center's -River Analysis System (HEC-RAS), Surface-Water Modeling System-Sedimentation River Hydraulics-Two-Dimensional Modeling (SMS-SRH-2D), or GeoHec-Ras if available (See Figure 3.2.3). These models utilize actual survey data and would yield the most accurate results for the streambed slope.

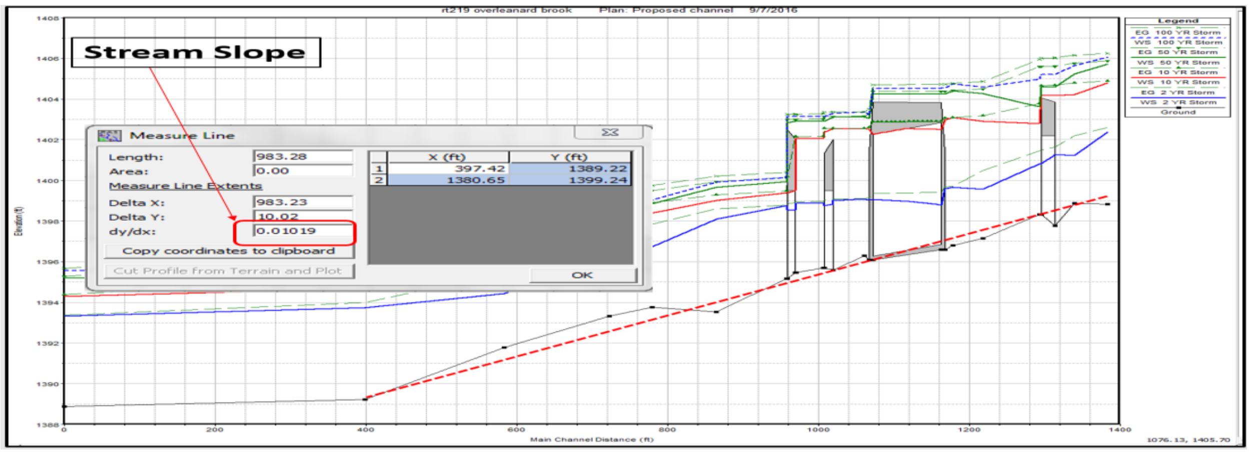


Figure 3.2.3 Stream Slope Determined from an Existing Hydraulic Model

Existing FEMA Flood Insurance Study

The slope of streambed can be obtained from existing FEMA Flood Insurance Studies if available (See Figure 3.2.4). These models also, utilize actual survey data and would yield accurate results for the streambed slope.

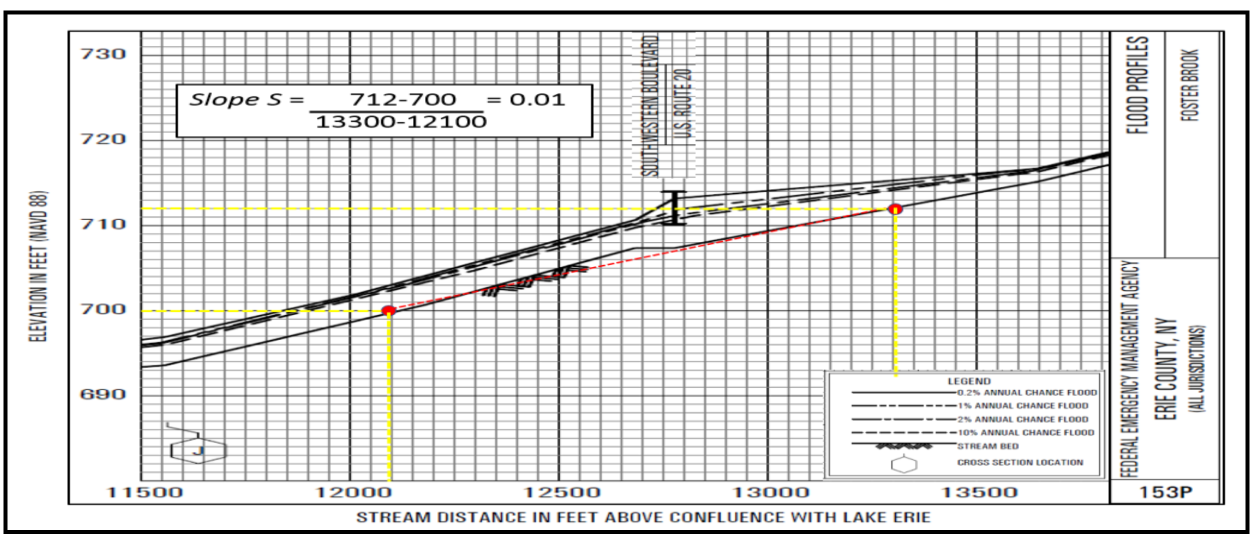


Figure 3.2.4 Streambed Slope Determined by FEMA Stream Profiles

Streambed Slope from StreamStats Profile

The slope of the streambed can be determined from the USGS StreamStats hydrologic program (See Figure 3.3.5). The Elevation profile tool can be used to digitize the stream from which the slope of the profile can be derived.

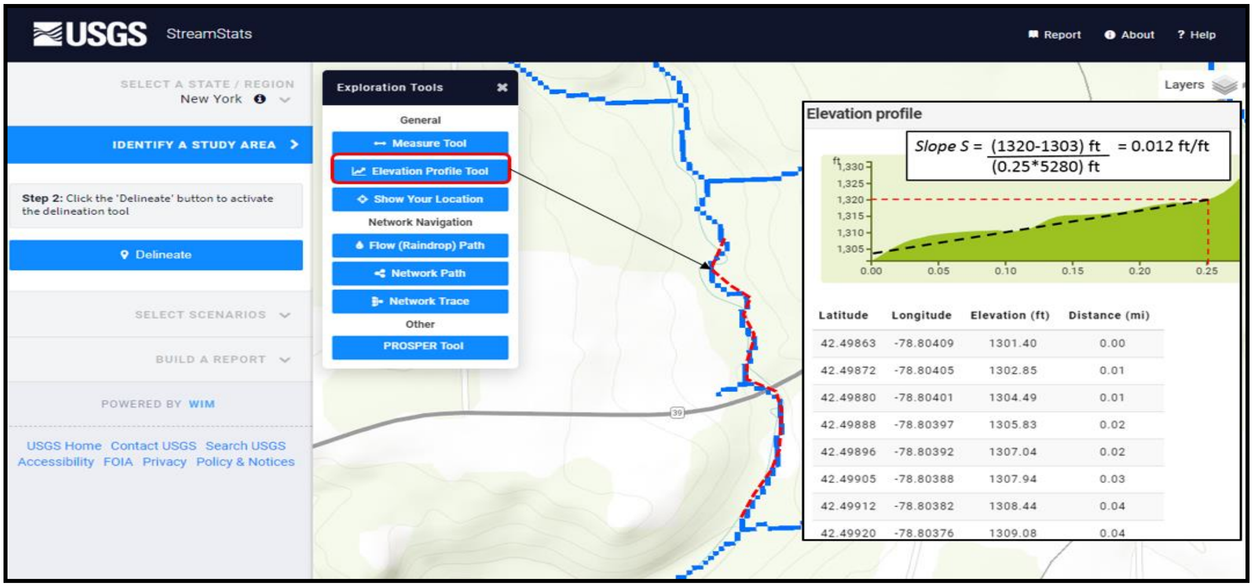


Figure 3.3.5 Stream Slopes from USGS StreamStats Online Tool

Profile Plot of Streams from Watershed Modelling Systems (WMS)

The slope of streambed can be determined from Watershed Systems Software (WMS) (See Figure 3.2.6). The measuring tool can be used to digitize the stream from which the slope of the profile can be derived.

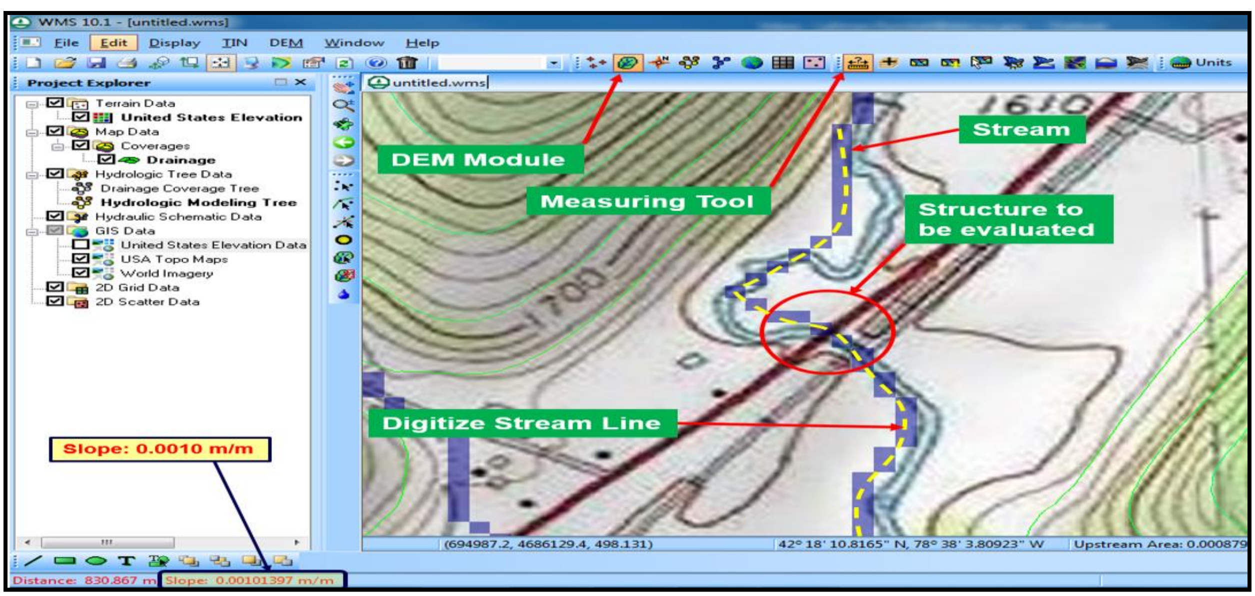


Figure 3.2.6 Streambed Slope using Watershed Modeling Software (WMS)

Determine Stream Slopes Using USGS Quad Maps.

The slope of the streambed can be determined from a USGS Quadrangle Map (See Figure 3.2.7). This is the least accurate method that can be used to determining stream slopes and should only be used when other methods describe in 1 - 4 are not available. This method utilizes a scaled image file or hard copy of a USGS Quad Map where the elevation is determined by contour lines 500 feet upstream and 500 feet downstream of the bridge. The slope of the stream is then determined from this data.

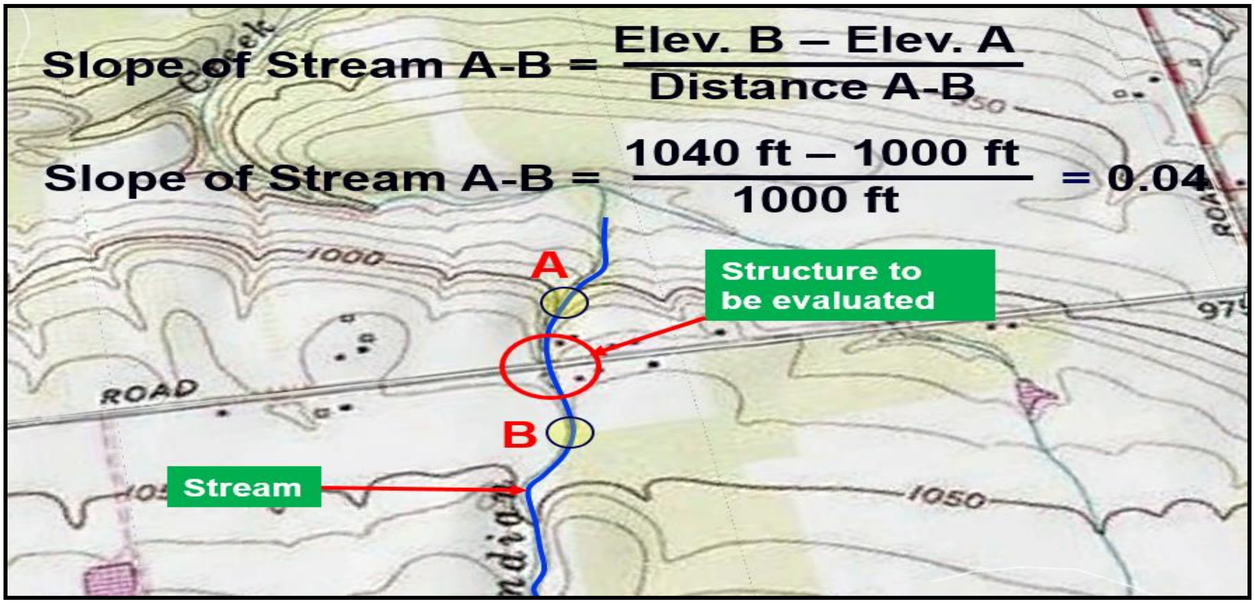


Figure 3.2.7 Streambed Slope Determined from USGS Quad Maps

b. Channel Bottom

The deposition or removal of material from the stream channel in the vicinity of a bridge can influence the scour vulnerability or the capacity of a structure. Four stream channel conditions: Aggrading, Stable, Degrading and Countermeasures Installed, are described below.

- An **Aggrading** channel condition can decrease the scour potential at a bridge by providing extra material for removal during a flood. The negative effects of severe deposition which restricts flow capacity and affects the flow patterns. See **i. Adequate Opening**, for additional information on effects of an Aggrading channel.

- A **Stable** channel condition can represent potential for a scour-prone condition when compared to an Aggrading channel.

- A **Degrading** channel is the most scour-prone condition. A range of values is provided to allow the engineer to account for varying levels of degradation.

- A channel with **Countermeasure Installed** is a channel that has in-stream structures to mitigate an Aggrading or Degrading channel. Countermeasures that are not functioning as designed or that have completely failed, should be rated as either Aggrading, Stable or Degrading.

Table 3.2.2 Channel Bottom Scores

CHANNEL BOTTOM				
Aggrading	Stable	Degrading	Countermeasure Installed	
			Good	Poor
0	1	2-5	1	3

Stream bed changes, degradation or aggradation or countermeasures can be determined by any of the following methodologies:

- Comparing Record Plans with current stream bed measurements (See Figure 3.2.8).
- Reviewing Bridge Inspection Dropline/Cross-Section reading(s) over many years of record (See Figure 3.2.9 & 3.2.10).
- Stream channel hydraulic variables (such channel scour), Condition State (CS) can also be reviewed in the Bridge Inspection Reports when assigning a score to this variable.
- Field investigation of the channel in the vicinity of the bridge, and the condition and performance of any grade control countermeasures in the vicinity of the bridge.

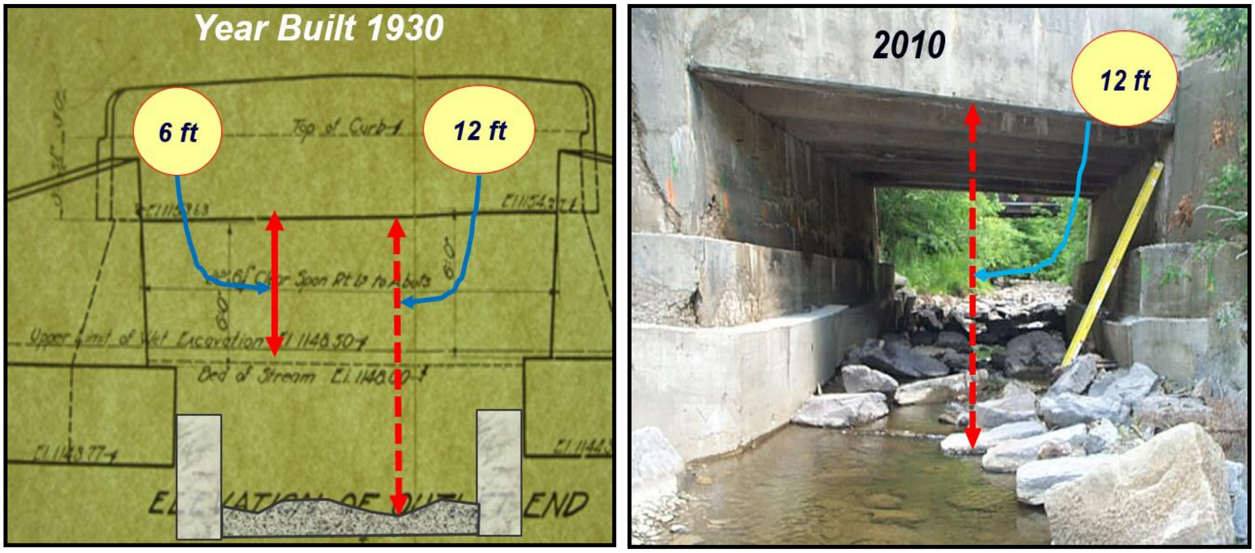


Figure 3.2.8 Stream Bed Degradation Based on Record Plans Measurement

If the Record Plans of the structure are not available, then Inspection Reports can be used to compare current and historic stream bed elevations. For this, review Bridge Inspection Dropline/Cross Section Reading(s) over many years of records.

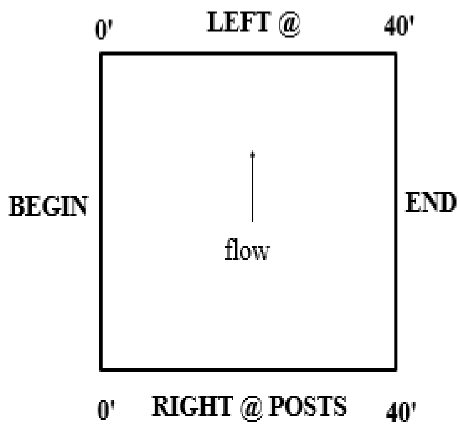
Bridge inspectors are required to take channel cross-section readings (droplines) along the upstream and downstream fascia of the bridge during every general Inspection, according to guidelines outlined in the NYS Bridge Inspection Manual. This data is collected and compared to baseline data that was taken when the structure was built or the oldest dropline data available for the structure. The amount of aggradation or degradation can be derived by comparing this data.

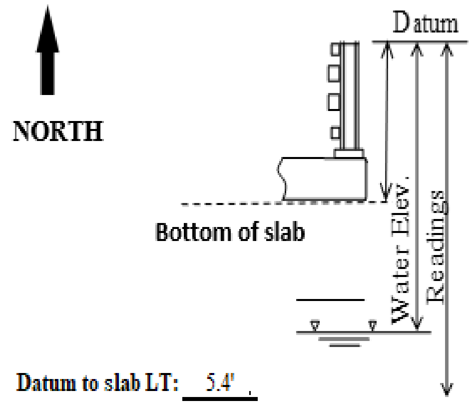
Additionally, Countermeasures Installed is an assessment of a countermeasure, such as a check-dam, rock-sill, or a cross-vane, etc., in the channel or just upstream/downstream of a structure. Countermeasures can arrest long term and/or local streambed degradation under the bridge. The effectiveness of the countermeasure will depend on how well it was designed, installed and functioning.

Any countermeasure installed should supersede the degrading scores. However, if countermeasures are not functioning as designed or failed, countermeasures should not be rated. At which point, guidance for an aggrading, stable or degrading channel should be followed. Channel bottom geomorphology can be influenced by natural and/or man-made changes within the channel. Gravel mining, removal, or installation of a dam upstream or downstream of a structure, can lead to significant changes to the streambed in the vicinity of the bridge. All streams degrade naturally over time. However, the rate at which streambeds degrade naturally is influenced by their geographic locations, the geomorphological stage of the river development, and/or climate change factors.

RC RC BIN 5555555

CHANNEL CROSS SECTION READINGS (Dropline):





Datum to slab LT: 5.4'

Datum to slab RT: 5.4.

LEFT FASCIA READINGS

Date	2004	2012	2014	2016	2018	2020
Station/TL	TK	RR	LR	AB	NS	TK
0'	13.3	13.7	13.9	13.5	13.8	13.5
5.6	14.8	14.4	14.2	14.4	14.0	14.7
12.6	14.9	15.0	14.3	14.3	14.6	14.5
19.6	15.6	15.0	15.0	15.1	15.4	15.2
26.6	16.0	15.2	15.4	15.6	15.9	15.7
33.4	15.9	15.2	15.4	15.8	16.5	15.8
40	14.4	14.2	14.6	15.3	15.8	15.1
W.Elev						
@ Sta.						
To footing			NA			

RIGHT FASCIA READINGS

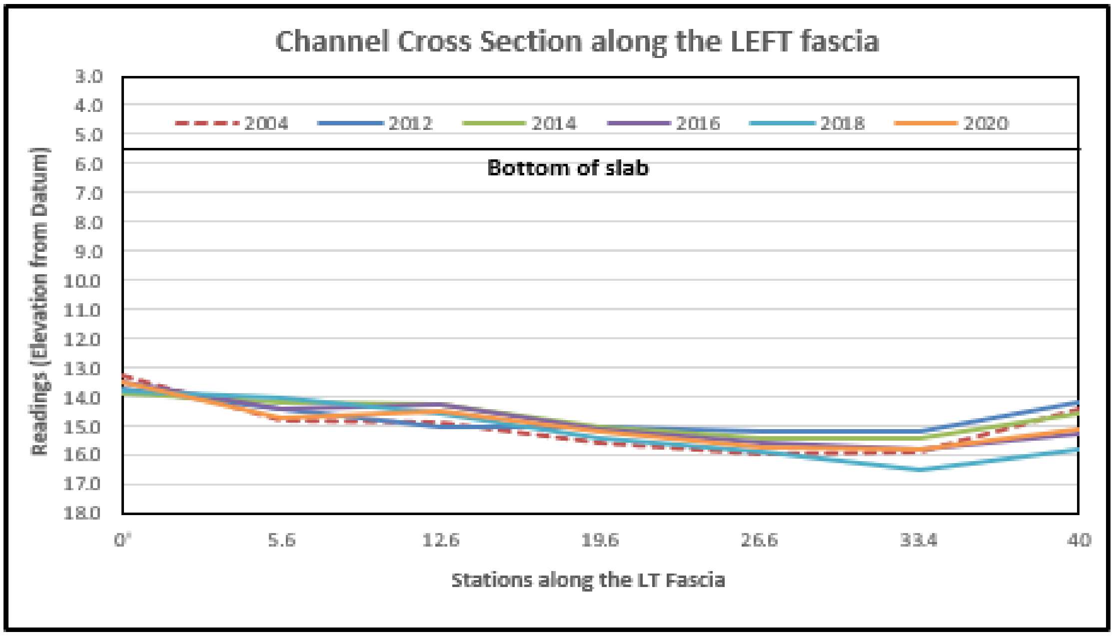
Date	2004	2012	2014	2016	2018	2020
Station/TL	TK	RR	LR	AB	NS	TK
0'	13.3	13.0	11.6	12.4	12.5	12.2
6.7	13.8	12.9	12.1	12.9	12.8	12.6
13.7	14.6	14.3	13.1	13.9	13.5	13.9
20.7	15.2	14.8	13.1	15.0	15.8	15.4
27.7	15.6	15.3	14.5	15.4	16.2	15.8
34.7	15.6	15.0	15.0	15.4	15.3	15.2
40	13.9	13.8	14.0	14.1	14.0	14.0
W.Elev	15.1	14.6	14.0	14.9	14.8	14.2
@ Sta.	20.7	20.7	20.7	20.7	20.7	20.7
To footing			NA			

Date:	Comments
2004	Baseline readings, new bridge.
2012	1.2' siltation at 0+06.7 right since previous inspection.
2014	No significant changes within the flow channel since baseline readings.
2016	No significant changes from baseline and 2012 readings. 2014 reading at station 0+27.7 right appears to be a typo.
2018	Max degradation of 1.4 feet at station 0+40.0 left and max aggradation of 1.1 feet at station 0+13.7 right since baseline.
2020	No significant changes since baseline.

Figure 3.2.9 Channel Cross Section Readings (Dropline)

RC _RC_ BIN _5555555_

CHANNEL CROSS SECTION READINGS (Dropline - graph of channel's bed):



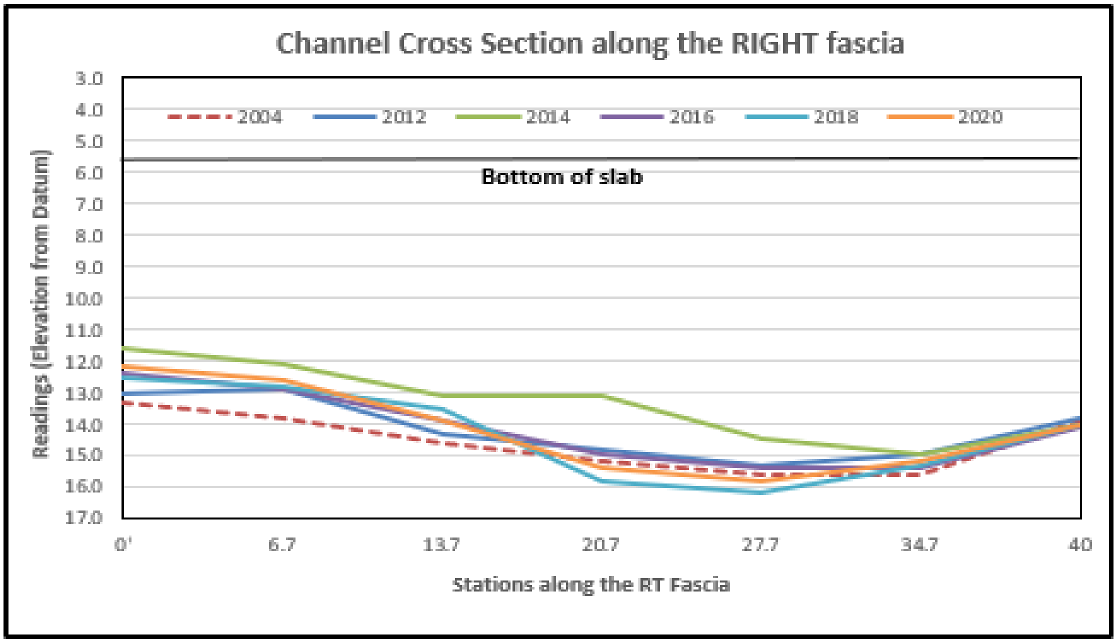


Figure 3.2.10 Channel Cross Section Readings (Graph)

Channels that show no significant changes over several years in Dropline Reading(s) along bridge facias and/or minimal channel degradation upstream and downstream are considered stable (See Figure 3.2.11 & 3.2.12).

Example of a Stable Channel

Figure 3.2.11 Stable Channel Example

Example of a degrading Channel

Figure 3.2.12 Degrading Channel Example

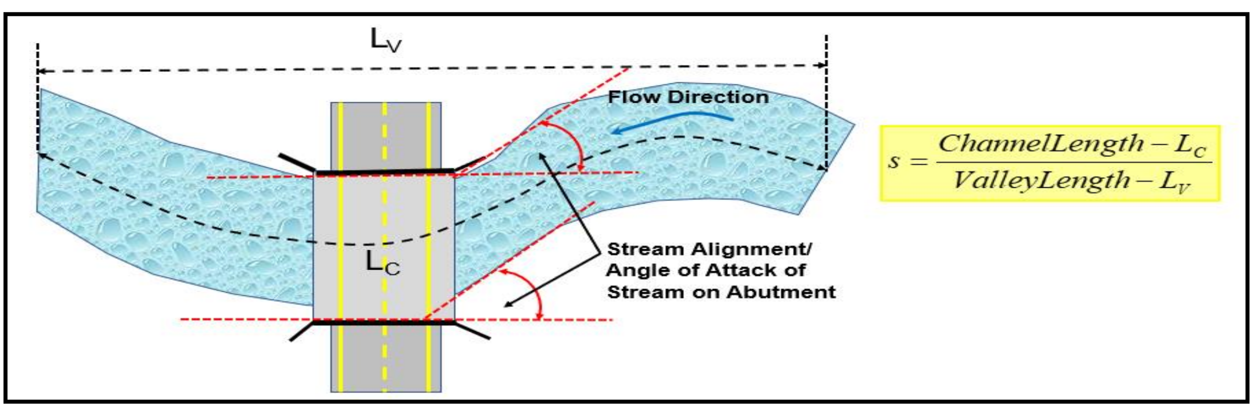
The presence of grade control countermeasure(s) (See Figure 3.2.13) and their condition may be determined by field investigation and/or review of Bridge Inspection Reports. Countermeasure functioning as designed can be rated in good condition (Condition States of 1 - Good and 2 - Fair) from the bridge inspection report. Countermeasures not functioning as designed or that have generally failed can be rated in poor condition (Condition States of 3 - Poor and 4 – Severe) from the bridge inspection report. Countermeasures that have completely failed should not be rated as having Countermeasures Installed and guidance on an aggrading, stable, or degrading channel should be followed. Figure 3.2.13 shows examples of countermeasures that are in good and poor conditions.

Countermeasure – Stone/Sheetpile Grade Stabilization Structures

Figure 3.2.13 Grade Stabilization Structures

c. Channel Configuration/Alignment

The stream channel configuration in the vicinity of the bridge can contribute to the potential for abutment or pier scour or both. Three terms are used to describe stream channel configurations: Straight, Braided and Meandering. The Sinuosity (s) (See Figure 3.2.14) and the alignment of the stream as it enters the bridge are key variables for determining the channel configuration. A brief description of these different configurations is included below. More detailed descriptions and illustrative examples can be found below and in **Section 5.8.1 of the River Engineering for Highway Encroachments (HDS 6).**



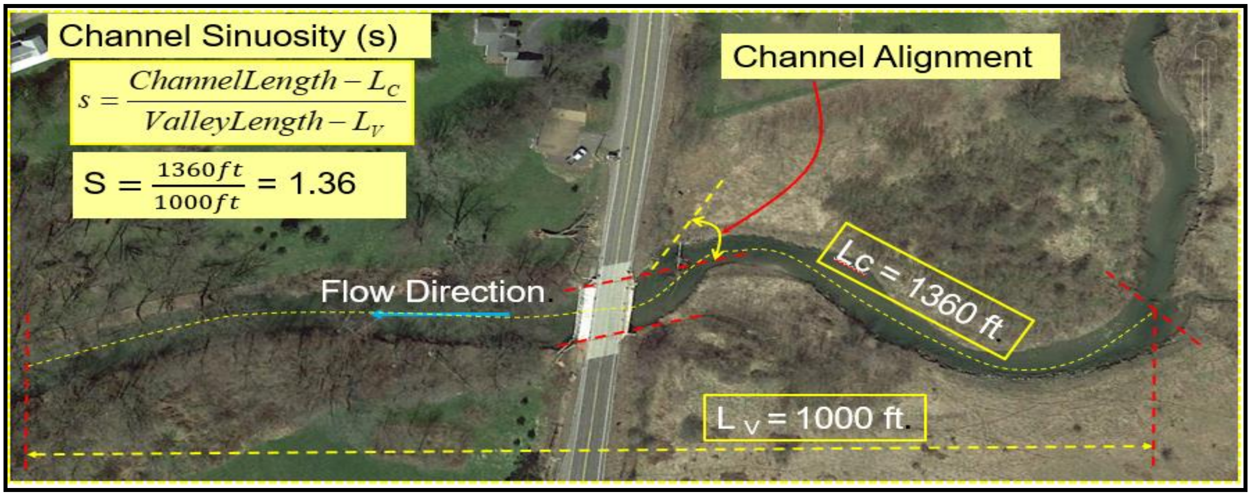


Figure 3.2.14 Stream Sinuosity (s)

- A **Straight** channel is defined as exhibiting a Sinuosity of less than 1.5, or the upstream channel aligns itself with the bridge abutments, between 0-15 degrees. This channel type is the least likely to effect scour. However, if a straight channel has gravel bar formations that shift the Thalweg, the classifying score should be increased.

- A **Braided** stream has various channels that are continually changing. If channels shift under the bridge, or if two channels come together at an abutment or pier, the potential for scour will increase. However, a Braided channel is generally more stable than a Meandering channel.

- A **Meandering** stream has an "S" shape continually moving laterally and downstream. The angle the upstream channel makes as it approaches the bridge abutment can erode approach embankments and cause changes in the direction of the flow. Primarily because the stream channel may migrate laterally to effect abutments, piers, or culverts. This configuration has the highest potential to cause scour problems.
- **Countermeasures** installed to mitigate/arrest lateral migration of the stream and redirect stream flow in line with the bridge abutments would reduce the overall local scour at bridge piers. The score for a poor stream alignment should be reduced because of the installation of these countermeasures. When rating based on "Countermeasures Installed" both quantity and condition should be considered.

Table 3.2.3 Stream Configuration/Alignment Scores

STREAM CONFIGURATION/ALIGNMENT						
s < 1.5	Braided	Stream Meander s > 1.5			Countermeasure Installed	
Straight		Stream Alignment/Angle of Attack (Degrees)				
0-15 Degrees		15-30	30-45	>45	Good	Poor
0	1	2	3-4	5	1	3

The reach of stream which should be looked at when deciding on a channel configuration depends on how well formed the channel is, how stable the banks are with either rock or vegetative cover and whether the material in the stream and banks can be easily eroded. Less stable conditions would require longer reaches to be examined and would result in higher stream alignment scores. As a minimum, however, 500 to 1,000 feet upstream and downstream of a bridge should be used.

Stream channel alignment can be determined from one or more from the following data sources:

1. Field Investigation
2. Bridge Inspection Reports
3. Aerial Photographs

1. Field Investigation: A field investigation would help determine channel alignment as it approaches the upstream fascia of the bridge (See Figure 3.2.15). Channel and embankment conditions such as erosion, condition of vegetation and/or bank protection, installation of countermeasures, etc. can be determined from a site investigation.

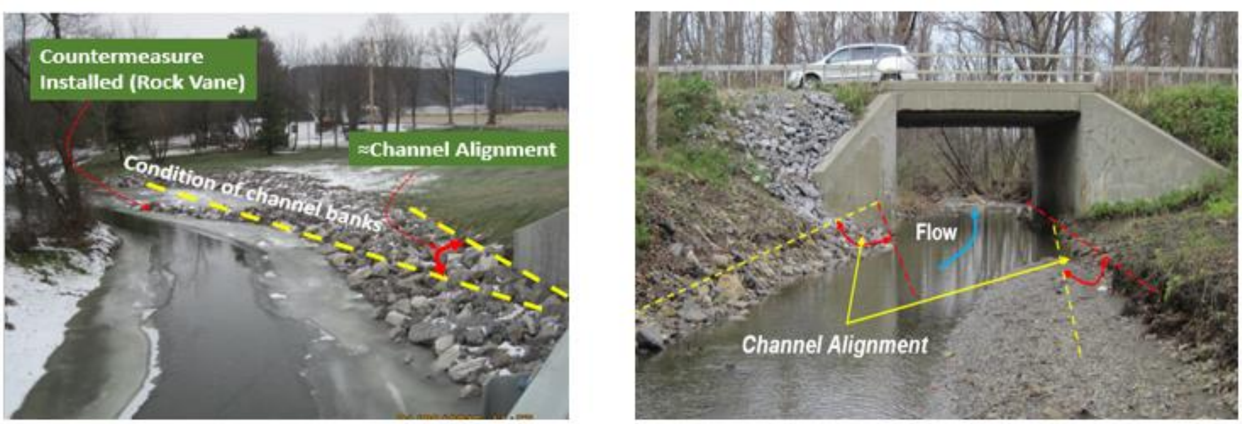


Figure 3.2.15 Field Investigation of Channel Alignment

2. Bridge Inspection Reports: Bridge Inspection Reports can also be used to determine current stream alignment or historical data. It contains useful information such as the angle the stream makes with the upstream fascia as it enters the bridge, sketches of the stream alignment if a significant stream defect exists, or several years of stream photographs upstream and downstream of the bridge (See Figure 3.2.16). It also contains records of stream channel and erosion and scour defects that may exist at the structure. Stream plots of channel deficiencies that are sometimes contained in the Bridge Inspection Report can be examined for channel alignment and banks and stream conditions. Refer to NYSDOT Bridge Inspection Manual for Stream Hydraulic Defect(s) definitions. However, if conclusive data cannot be obtained from the Bridge Inspection Reports, a field investigation is recommended.

Agency Defined Element 801 - Stream Hydraulics Defect History

ADE 801 DEFECTS		CONDITION STATES (CS)			
		Previous Inspections			Current Inspection
		21/07/2000	15/06/2002	20/06/2004	14/06/2006
6120	Channel Alignment	2	2	3	4
6130	Channel Scour	1	1	1	1
6140	Waterway Opening	1	1	2	1
6150	Scour Protection	NA	NA	NA	NA
6160	Bank Protection	NA	NA	NA	NA
6165	Bank Erosion	1	1	3	4
6180	Debris Near Bridge	1	1	2	1
6190	Countermeasures	NA	NA	NA	NA
ADE 801 - Controlling Condition State =					4

Figure 3.2.16 Bridge Inspection Reports for Channel Alignment (ADE 801)

3. Aerial Photographs: Aerial photographs are avaiable from Counties, NYSDOT Survey Unit, and most commonly Google Earth Files. However, they may not be updated, but useful information such as channel alignmment and/or sinuousity can be obtained from aerial photographs. Historical channel migration can also be obtained from these files. However, if conclusive data

cannot be obtained from aerial photographs, a field investigation is recommended.

d. Debris/Ice Problem

Watershed, river conditions, or abutments, piers and culvert configurations that promote debris and ice accumulation increases potential scour depth by either reducing the conveyance area or by increasing the effective width of the substructures (See Figure 3.3.17). The determination that a debris or ice problem exists is primarily made through an examination of historic records or field observations. Also, the ability for a structure to pass debris and sediment together with the ability of the watershed and stream to produce significant debris load should be considered when assigning a score for this variable. The following condition should be assessed:

Clear opening spanning the entire channel process debris more efficiently than an opening that just spans low flow channel

Figure 3.2.17 Clear Opening Vs. Low Flow Opening

1. Piers located within the floodway have a greater risk of catching debris and/or promoting ice jams during high flow events (See Figure 3.2.18). Flow constriction minimizes the ability for a structure to pass debris and ice during high flow events.

Piers located along the edge of the floodway has less ability to snag debris and ice than piers located within the floodway

Figure 3.2.18 Multiple Piers in the Floodway

2. Multiple cell culvert structures have less ability to convey ice and debris through the structure than single cell structures.

3. Channels with eroding banks upstream have more ability to produce debris during storm events than channels with stable banks (See Figure 3.2.19).

Stable Channels tends to produce less debris   Unstable Channels tends to produce more debris

Figure 3.2.19 Stable Vs. Unstable Stream Banks

4. Channel bends just downstream or at the upstream fascia of a structure promotes the likelihood of ice and debris jams (See Figure 3.2.20).

Figure 3.2.20 Channel bends promoting Ice and Debris

If conditions are unknown, the engineer should use judgment in assessing using illustrations noted above and guidance below.

- Bridges with no history of ice or debris problem should be placed in the *no effect category*.

- The *minor effect category* is for structures which have experienced ice or debris buildup only occasionally or under unique or severe conditions and those which have shown no signs of damage from the buildup.

- The *major effect category* is for bridges with a history of severe or recurring ice and debris problems.

Table 3.2.4 Debris/Ice Problem Scores

DEBRIS / ICE PROBLEMS					
No Effect	Minor Effect		Major Effect		
0	1	2	3	4	6

e. Near River Confluence

A bridge located in the vicinity of a river confluence has the potential for increased flow and velocity and a resultant increase in scour potential. Both upstream and downstream confluences are of concern for this parameter (See Figure 3.2.21). Determination of this parameter can be obtained by examining aerial photographs and/or USGS Quad maps.

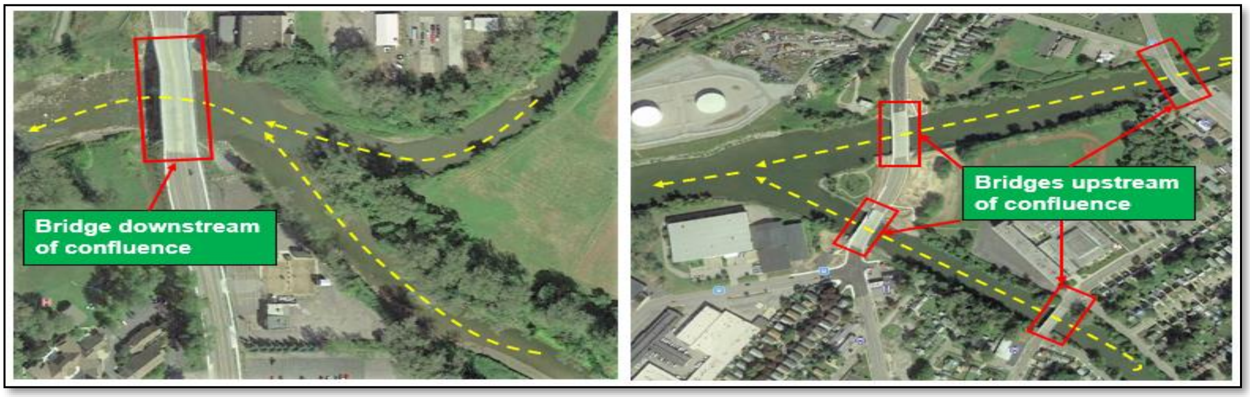


Figure 3.2.21 Near River Confluence

Table 3.2.5 Near River Confluence Scores

NEAR RIVER CONFLUENCE	
NO	YES
0	1

f. Affected by Backwater

Locations affected by backwater for all flow conditions, primarily resulting from proximity to a dam, are of concern for this parameter. Backwater from a downstream waterway should not be considered because it may not occur concurrently with peak flow and velocity on the tributary and at the location being studied.

Determination of this parameter can be obtained by examining aerial photographs and/or USGS Quad maps (See Figure 3.2.22). Backwater from a lake can also be considered under this parameter if the lake water surface levels have little seasonal fluctuations and provide a constant relatively high tailwater at the bridge.

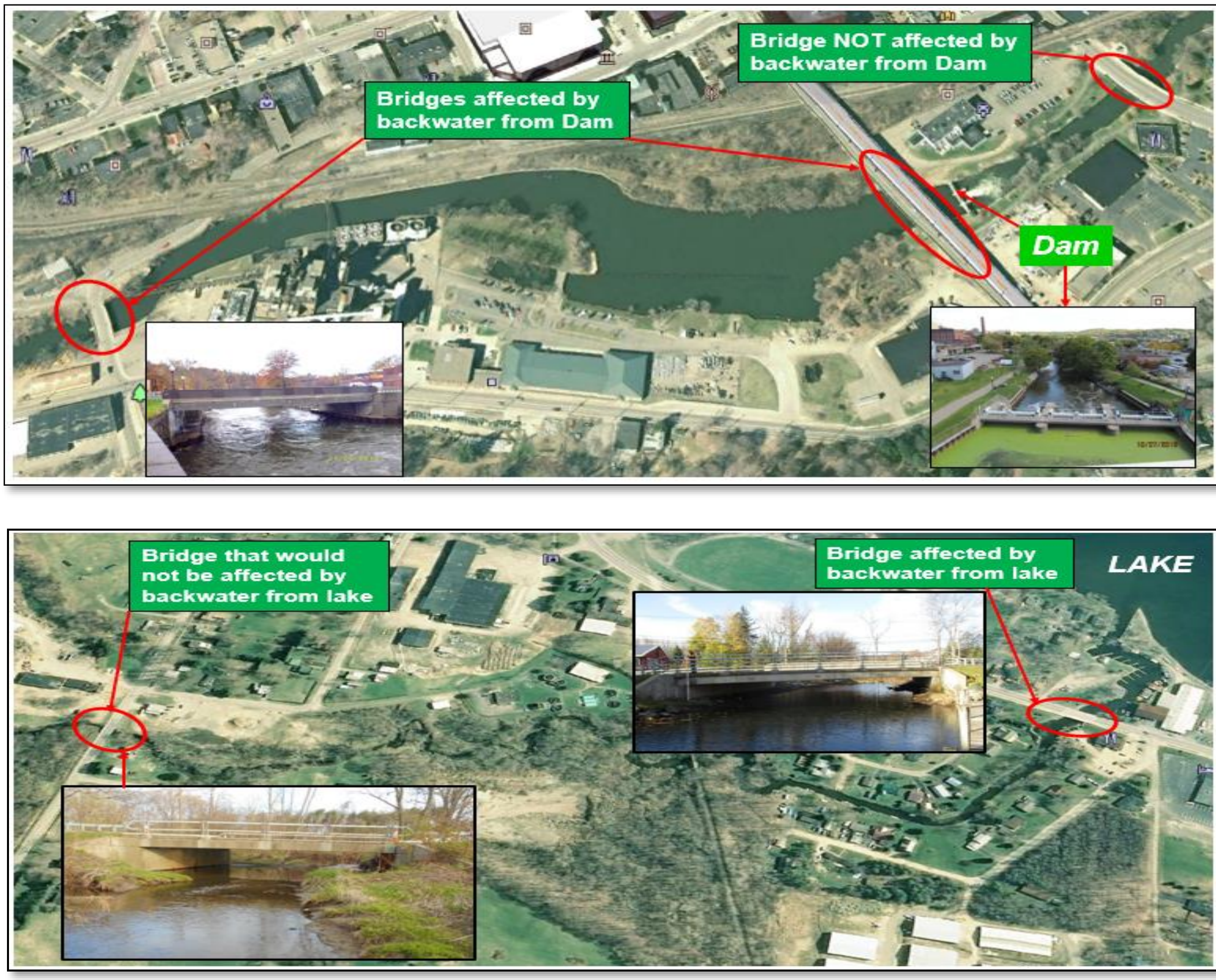


Figure 3.2.22 Affected by Back Water Illustrations

Table 3.2.6 Affected by Backwater Scores

AFFECTED BY BACKWATER	
YES	NO
0	1

g. Evidence of Existing or Historic Scour Depth

Bridges with a history of scour problems have a clear potential for continued and increased scour activity. Even small signs of scour are significant because scour holes tend to refill with material as the scour event subsides. This redeposited material is quickly removed in subsequent scour events, increasing the susceptibility of the structure. A clue which indicates past scour activity is the presence of buried debris around a foundation. If debris is found buried around the nose of a pier, it can be assumed that material has been previously scoured and redeposited.

At Concrete Box Culverts, it is important to look for evidence of scour at the inlet and the outlet and where the culvert joins the wingwalls. Shifting of the wingwalls or a change in the joint spacing between the box and the wingwall could indicate scour under the wingwall footings. Shifting and movement between adjacent box sections could indicate piping and undermining of the main part of the culvert. Other signs of distress are the formation of a localized scour holes or changes in the streambed elevation.

At Metal Pipe Culverts, in addition to undermining of the ends or shifting of the headwalls, it is also important to look at the condition of the pipe to observe if there are any deformations which would indicate a loss of soil support.

Evidence of Existing or Historic Scour Depth can be determined by reviewing any or all of the following:

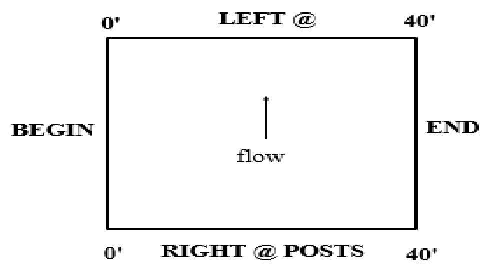
1. Reviewing Bridge Inspection Dropline/Cross Section Readings and the stream Profile Along Abutments/Piers over several years of records.

   Bridge inspectors are required to take bridge and channel cross section data along the upstream and downstream fascia during every general inspection, according to guidelines outlined in the NYS Bridge Inspection Manual (See Figure 3.2.23). This data is collected and compared to a baseline data that was taken when the structure was built or the oldest dropline data available for the structure. Some dropline data may include footing elevations that are very useful in determining Existing or Historic Scour Depths. The amount of scour occurring can be derived by comparing this data.

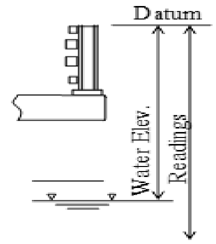
   Stream profile readings are sometimes taken along bridge abutment/pier foundations to document scour (See Figure 3.2.24). A review of this data will also provide useful information regarding the extent of scour at bridge foundations.

RC RC BIN XXXXXXX

CHANNEL CROSS SECTION READINGS (Dropline):



NORTH



Datum to slab LT: 5.4'
Datum to slab RT: 5.4.

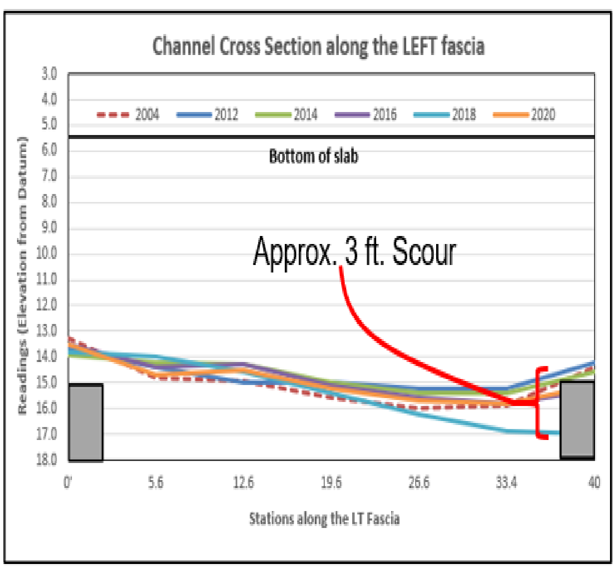
LEFT FASCIA READINGS

Date	2004	2012	2014	2016	2018	2020
Station/TL	TK	RR	LR	AB	NS	TK
0'	13.3	13.7	13.9	13.5	13.8	13.5
5.6	14.8	14.4	14.2	14.4	14.0	14.7
12.6	14.9	15.0	14.3	14.3	14.6	14.5
19.6	15.6	15.0	15.0	15.1	15.4	15.2
26.6	16.0	15.2	15.4	15.6	16.2	15.7
33.4	15.9	15.2	15.4	15.8	16.9	15.8
40	14.4	14.2	14.6	15.3	17.0	15.1
W.Elev						
@ Sta.						
To footing			NA			

RIGHT FASCIA READINGS

Date	2004	2012	2014	2016	2018	2020
Station/TL	TK	RR	LR	AB	NS	TK
0'	13.3	13.0	11.6	12.4	12.5	12.2
6.7	13.8	12.9	12.1	12.9	12.8	12.6
13.7	14.6	14.3	13.1	13.9	13.5	13.9
20.7	15.2	14.8	13.1	15.0	15.8	15.4
27.7	15.6	15.3	14.5	15.4	16.4	15.8
34.7	15.6	15.0	15.0	15.4	17.1	15.2
40	13.9	13.8	14.0	14.1	17.5	14.0
W.Elev	15.1	14.6	14.0	14.9	14.8	14.2
@ Sta.	20.7	20.7	20.7	20.7	20.7	20.7
To footing			NA			

Date:	Comments
2004	Baseline readings, new bridge.
2012	1.2' siltation at 0+06.7 right since previous inspection.
2014	No significant changes within the flow channel since baseline readings.
2016	No significant changes from baseline and 2012 readings. 2014 reading at station 0+27.7 right appears to be a typo.
2018	Max degradation of 2.7 feet at station 0+40.0 right and max aggradation of 1.1 feet at station 0+13.7 right since baseline.
2020	No significant changes since baseline.



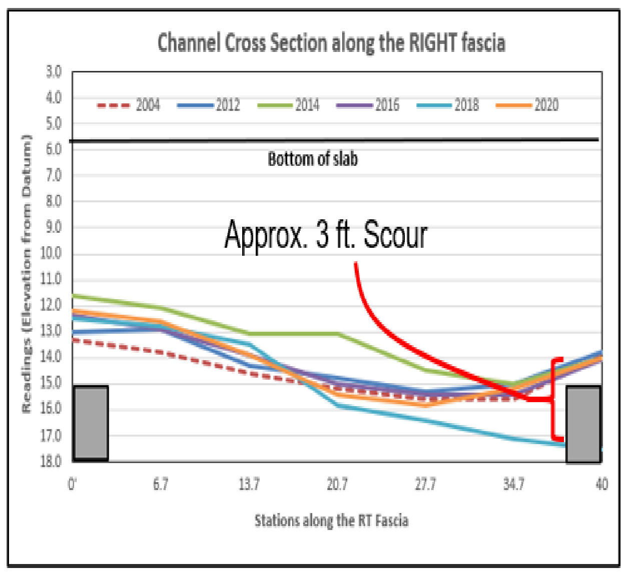


Figure 3.2.23 Channel Cross-Section Readings & Graph

NYS DEPT. OF TRANSPORTATION

R/C BIN ______ DATE: 4/3/2020

FEATURE CARRIED: ______

FEATURE CROSSED: ______

CH# NDERMINING
ALONG END ABUTMENT

READINGS (ft)									
YEAR →	2018			2019			2020		
STA.	D(ft)	V(ft)	H(ft)	D(ft)	V(ft)	H(ft)	D(ft)	V(ft)	H(ft)
-0+02	3.0	0.5	1.0	1.8	-	-	1.8	-	-
0+00	1.7	-	-	1.7	-	-	1.7	-	-
0+05	2.0	-	-	2.0	-	-	2.1	-	-
0+10	2.6	0.1	1.0	2.1	-	-	2.1	-	-
0+12	2.6	0.1	2.1	2.1	-	-	2.2	-	-
0+15	2.8	0.3	2.0	2.5	-	-	2.5	-	-
0+20	3.0	0.5	2.5	2.7	-	-	2.5	-	-
0+21	-	-	-	2.8	0.3	1.0	2.8	0.3	2.1
0+25	2.9	0.4	4.0+	2.9	0.4	4.0+	2.8	0.3	3.7
0+28	-	-	-	3.1	0.6	4.0	3.1	0.6	3.5
0+30	3.1	0.6	3.2	3.1	0.6	3.1	3.1	0.6	3.0
0+31.5	-	-	-	3.1	0.6	3.5	3.1	0.6	3.2
0+33	3.1	0.6	3.5	3.1	0.6	2.7	3.2	0.7	2.8
0+35	3.0	0.5	2.2	3.0	0.6	2.7	3.1	0.6	2.8
0+38	1.3	-	-	1.5	-	-	1.5	-	-
0+40	2.2	-	-	A	-	-	A	-	-
0+45	A	-	-	A	-	-	A	-	-

A= Above Datum

WSE = Water Surface Elevation

NORTH

STA -0+02

STA 0+00

FLOW

STA 0+45

RDG'S REF @ STATIONS

REFERENCE

DATUM = TOP OF FOOTING
T = 2.5ft
W = VARIES 6.0ft-8.5ft
X = 1.0ft
21 H-PILES

YEAR	NOTES
2016	Increases in horizontal undermining, up to 0.5 feet.
2017	Previous undermining from sta.0 ft. to sta.10 ft. filled in.
2018	Additional undermining found at STA. 0+10 and 0+35.
2019	The undermined area is less than the previous inspection due to infilling. New Stas added, Stas with yellow highlighting.
2020	Increase in horizontal undermining up to 1.1 ft at STA 0+21. Otherwise, minor changes observed.

Figure 3.2.24 Stream Profile along the Abutment

2. Review of Previous Scour Flags or Post-Flood Inspections

   Scour flags may have been issued when footings are exposed and/or undermined. Post event inspections (Post-Flood Inspections) may also contain this data before the scour condition is fixed (See Figure 3.2.25). Engineers should look through all related tabs in BDIS and all local files to find any of the above-mentioned reports.

Figure 3.2.25 Post Flood Inspection of Existing/Historic Scour Depth

Four categories are used to evaluate this parameter. The score which is used should reflect the extent and depth of scour that is observed or known to have occurred.

- *None* is for bridges with no history of scour. These are the least vulnerable.
- *Small* is for evidence of less than 1 foot of sour.
- *Medium* is for evidence or records of 1 to 3 feet of scour.
- *Large* is for evidence of more than 3 feet of scour.

Table 3.2.7 Existing/ Historic Scour Depth

EXISTING /HISTORIC SCOUR DEPTHS			
NONE	SMALL	MEDIUM	LARGE
0	(< 1’)	(1’-3’)	>3’
	1	2-3	4-5

h. Historic Maximum Flood Depth

Depth of flow is a parameter in the scour prediction equations in which deeper flows can yield greater scour depths. Classifying scores is assigned for flood depths of less than 5 feet, between 5 and 10 feet, or greater than 10 feet.

The determination of historic flood depth prior to a detailed scour analysis, can be determined from either one or more of the following investigations:

1. Field Investigation: Clues such as watermarks on trees or painted on structures, or debris caught on superstructure are good indicators of high-water marks (See Figure 3.2.26).

Waterborne debris on branches

Waterborne debris on Superstructure

Figure 3.2.26 Field Investigation of Historic Maximum Flood Depths

2. FEMA Studies: Flood Profiles from existing FEMA Studies can be used to determine water depth at bridges (See Figure 3.2.27).

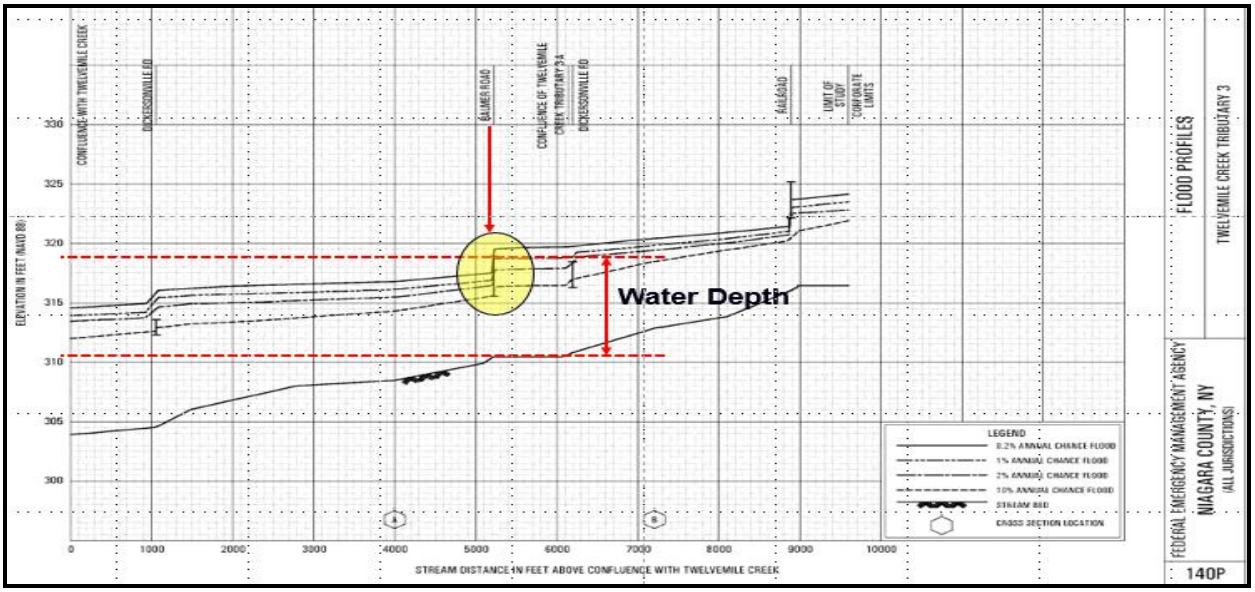


Figure 3.2.27 – FEMA Flood Insurance Study (Profile)

3. Record Plans: Most bridges built after 1990 would have the watersurface elevation (DHW) for the 50-year flood event shown on the record plans (See Figure 3.2.28). A determination of the flood depth/waterway adequacy can be made by reviewing these plans.

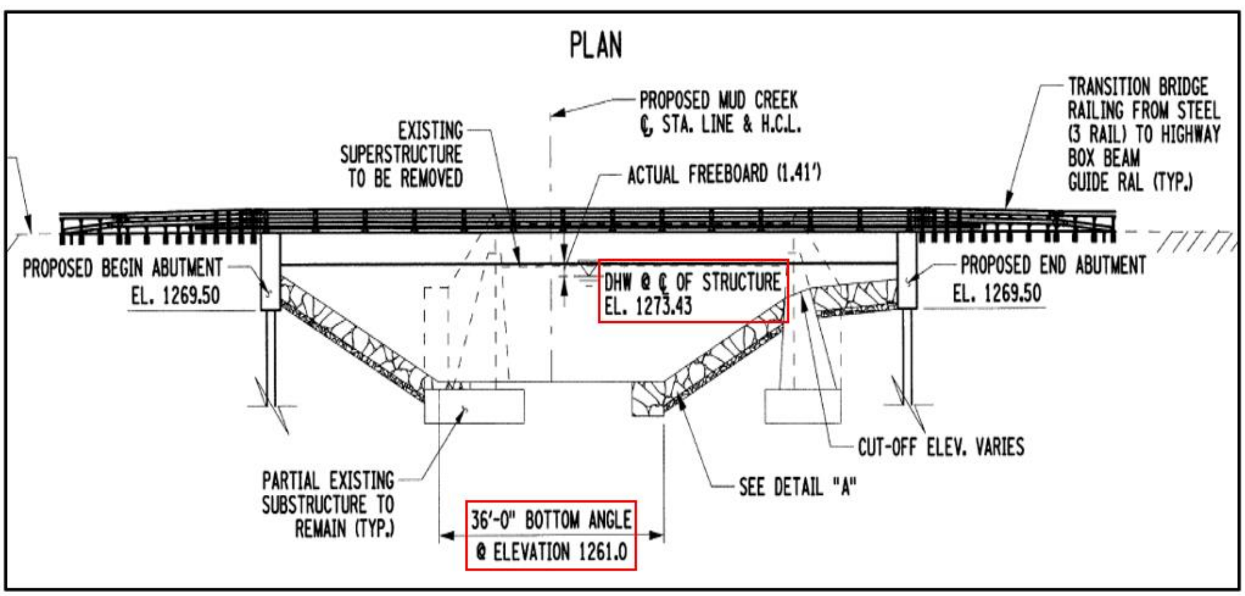


Figure 3.2.28 Record Plan with Design High Water (DHW)

4. Highway Maintenance Personnel/Residents: Carrying out interviews with maintenance staff, long-term local residence, or local historical societies can often help in determining historic flood depths.

   If the historic flood depth is unknown, then a value should be assumed. The assumed depth should be reasonable, accounting for the width of the channel and the floodplain and the size of the drainage area.

Table 3.2.8 Maximum Flood Depth Scores

MAXIMUM FLOOD DEPTHS		
SMALL (<5')	MEDIUM (5'-10')	LARGE (>10')
1	2	3

i. Adequate Opening

A bridge with too small an opening can increase the potential for scour at the structure. A history of overtopping or inundation of a structure, or damage to the highway approach embankments or other upstream features would indicate the opening is not of sufficient size. Comparing the size of a bridge's opening with nearby upstream and downstream crossings can also give an indication as to the adequacy of the opening. The opening can be restricted because of a design which contracts the stream channel or the floodplain, or the restrictions can be caused by the deposition of materials and debris at the bridge.

- An adequate opening that is considered good, should have the ability to pass a 100-year design flood (500-year design flood for interstate bridges) without causing any significant damage to the bridge or to any upstream features. It is also desirable that some amount of freeboard is available during the flood to pass the debris through the bridge opening.

- An inadequate opening will constrict the flow, increase velocities, and produce greater scour than an unrestricted opening. Inadequate openings can be categorized as Fair or Poor.

Note:

- Good Opening: Is a structure that passes the 50-year flood and 100-year flood with positive freeboard without water hitting the low cord. This structure will have the ability to pass ice and debris more frequently than structure with poor waterway opening.
- Fair Opening: Is a structure that passes the 50-year flood but has pressure flow for the 100-year flood events or flow in which the bridge low chord becomes inundated and the flow through the opening transitions from free surface to pressurized condition. This structure will

have the ability to pass ice and debris more frequently than a structure with poor waterway opening.

- Poor Opening: Is a structure that has pressure flow or overtopped by the 50-year flood and 100-year flood events. This structure will not have the ability to pass ice and debris during these storm events and can lead to an increase in velocities and scour at the structure.

Waterway adequacy can be determined using a similar investigation as that outlined when determining Existing/Historic flood depths.

Table 3.2.9 Waterway Opening Scores

ADEQUATE OPENING		
Good	Fair	Poor
0	3	5

j. Overflow/Relief Available

The ability of the design flow to proceed downstream by a means other than through the structure, usually by way of a relief structure or by overtopping the roadway embankment, reduces the scour potential at the structure being evaluated because the resultant discharge and velocity are less than would otherwise be the case.

Table 3.2.10 Overflow/Relief Available Scores

OVERFLOW/RELIEF AVAILABLE	
YES	NO
0	1

Overflow relief availability can be determined by one or more of the following:

1. Review of FEMA Flood Insurance Rate Maps
2. Field Investigation/Aerial Photographs
3. Hydraulic Studies if available

1. Review of FEMA Flood Insurance Rate Maps (FIRM)

   Overtopping of the approaches as indicated on a FIRM can be considered as an overflow relief during the 100-year flood event (See Figure 3.2.29)

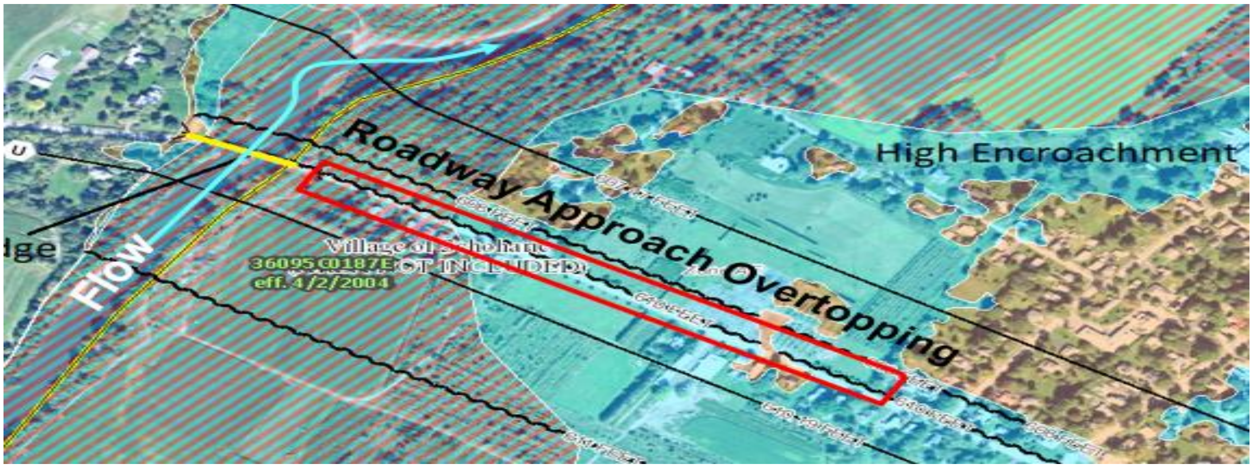
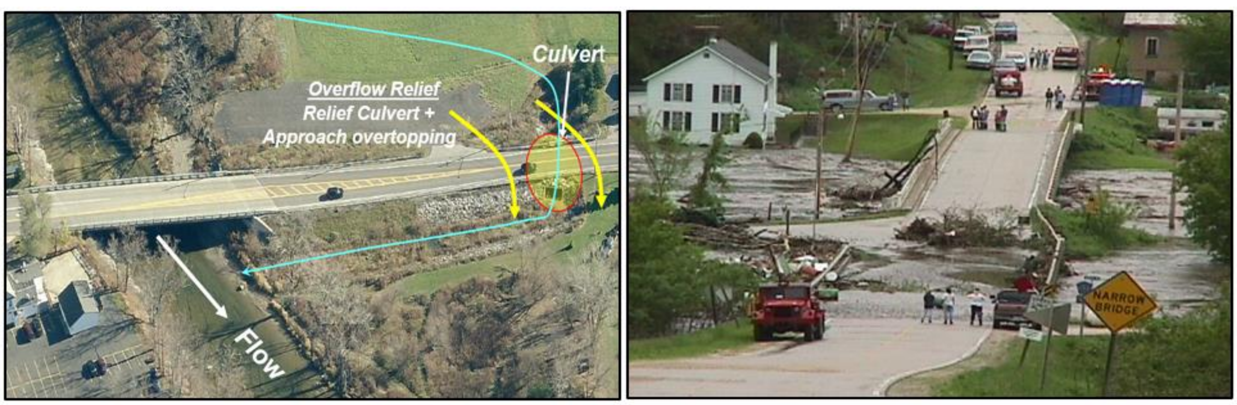


Figure 3.2.29 FEMA FIRM Map

2. Field Investigation/Aerial Photographs:

   Bridge Approaches that are lower than the low beam elevation and/or structures located under roadway approaches can contribute to overflow relief during the flooding events (See Figure 3.2.30).



Overflow availability determination from Field Investigation and/or Aerial Pictures

Figure 3.2.30 Overflow Relief illustration

3. Existing Hydraulic Studies/Record Plans:

Most bridges built after 1992 should have hydraulic studies completed and the results documented on the Record Plans. By examining the Hydraulic Analysis (See Figure 3.2.31) and/or reviewing the Record Plans, a determination can be made if there are relief features available for the bridge.

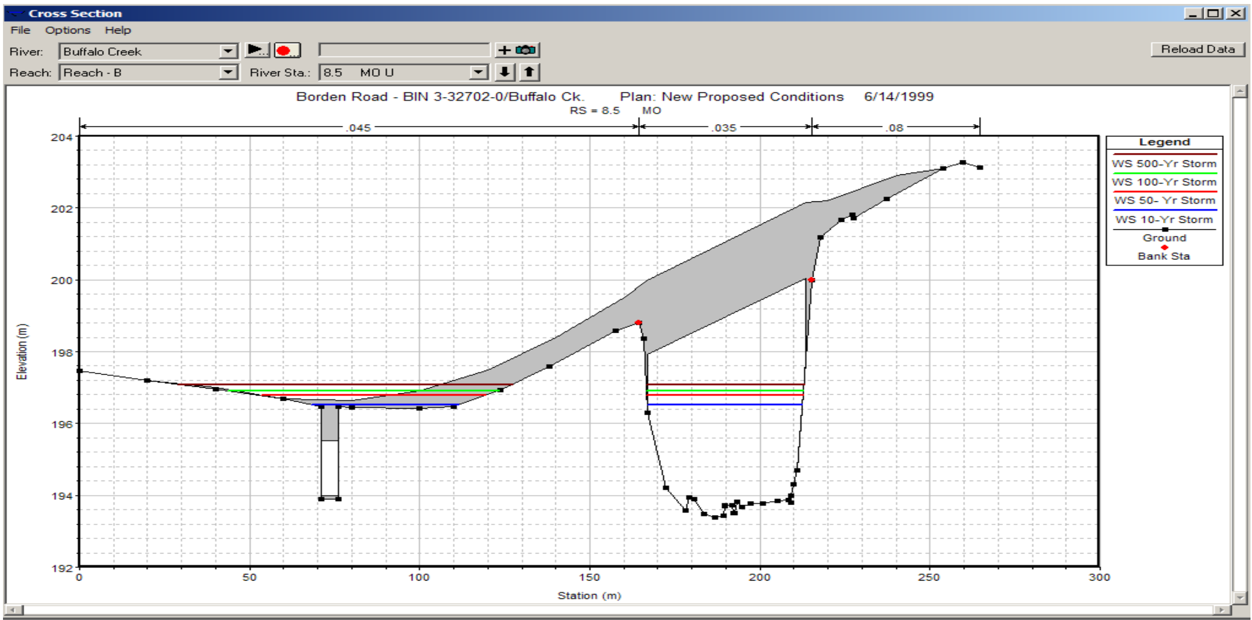


Figure 3.2.31 HEC-RAS Profile Plot

<u>The General Hydraulic Classification Score is totaled at the bottom of form 3.1 and entered on the summary sheet before proceeding to the Foundation Assessment section. See Form 3.1 in the "Forms" section of this manual.</u>

3.3 Foundation Assessment

The purpose of the Foundation Assessment section is to evaluate all of the abutments and piers on a bridge and identify the most critical unit. **<u>The Classification Score from the Critical Substructure is used as the Foundation Assessment Classification Score. This score is combined with the General Hydraulics Assessment Classifying Score to determine the Final Classification Score for a bridge.</u>**

3.3.1 Abutment

The abutment classifying process is shown in Form 3.3.1. This process is intended to evaluate the relative vulnerability of a bridge to scour considering factors that affect abutment scour. Form 3.3.1 will also be used to document the abutment assessment process. Each abutment should be evaluated separately because the scour producing parameters may vary, though it is expected that the abutment foundation configuration will be the same. The left and right directions are established looking downstream.

The parameters evaluated in the abutment assessment section reflect their relative effect on scour vulnerability. The rationale for their use are as follows:

a. Existing Scour Protection

Existing scour protection which provides protection to the abutment are considered in this parameter.

If protection is present but damaged to the extent that it is not *functioning as designed*, this should be reflected when classifying scores are assigned.

Locations that do not require scour protection should be given the lowest score for this parameter. These locations include but not limited to:

1. Abutments that are located completely outside of the floodplain (See Figure 3.3.1.1)

Figure 3.3.1.1 Abutments located outside the Floodplain

2. FEMA Rate Maps (FIRM), field investigation, hydraulic studies can help to determine if the abutments are completely out of the floodplain.

3. Abutments founded on non-erodible rock - Record Plans, inspection reports, field investigation can help determine if abutments are located on rock foundation that does not require scour protection (See Figure 3.3.1.2).

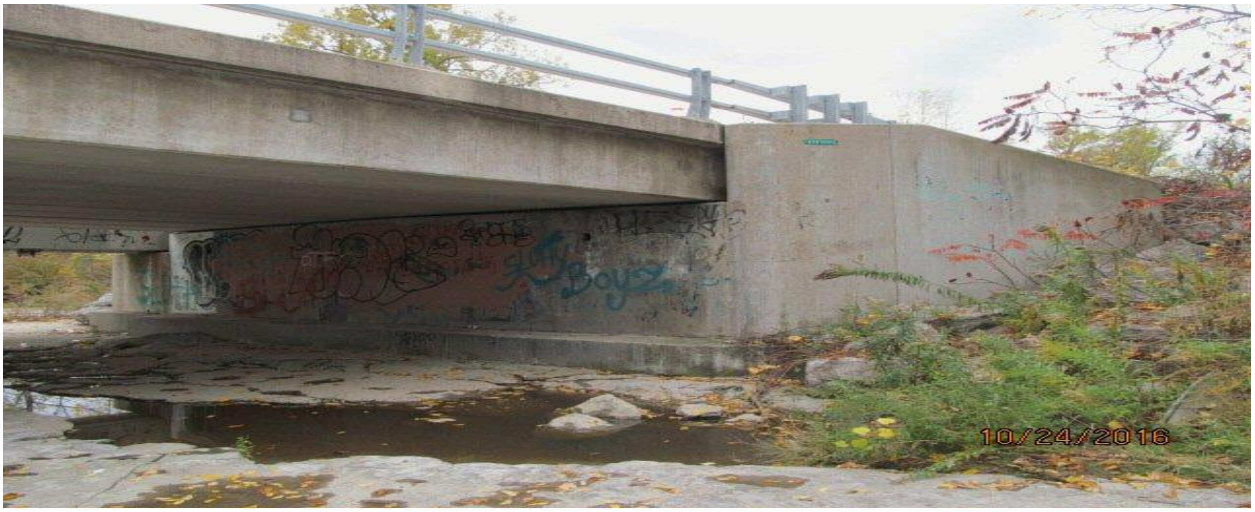
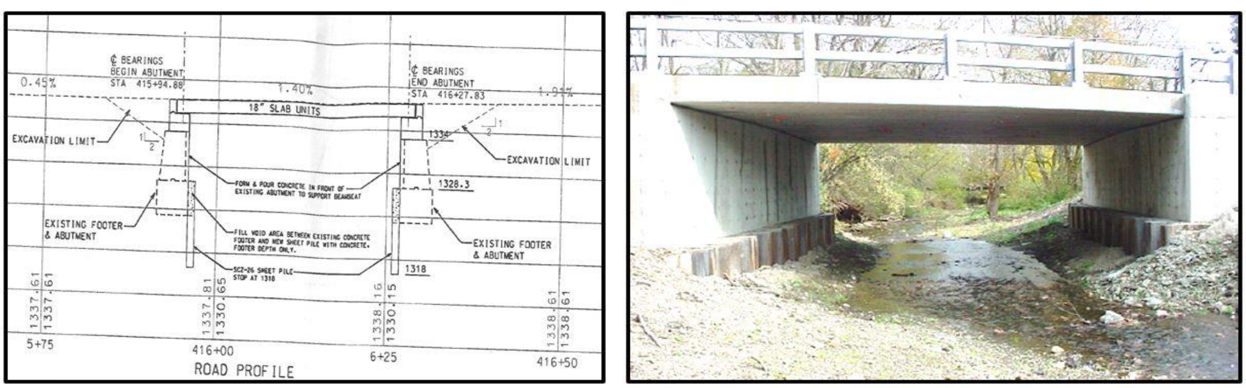


Figure 3.3.1.2 Abutments founded on Non-Erodible Rock

4. Record Plans, inspection reports and a field investigation can help determine if abutments are protected by sheet-pile cofferdams (See Figure 3.3.1.3).

Note: sheet-pile walls or cofferdams designed to resist scour represent a relatively permanent countermeasure and are therefore, given the lowest score. However, where sheet-pile scour protection exists, but no design details or depth of embedment are available, then a relative score can be assigned based on its performance. For example, a functioning sheet-pile sour protection should be scored a 1, whereas a sheet-pile scour protection that shows signs of failing and/or not functioning should be scored a 3.



Record Plans

Field Investigation

Figure 3.3.1.3 Record Plans indicating Sheet Pile Scour Protection

All other scour protection, including riprap are relatively more vulnerable than sheet-pile walls or cofferdams and are given higher scores. Their Condition States (CS) should be investigated by either reviewing Bridge Inspection Reports and/or a field investigation when assigning a score for this condition (See Figure 3.3.1.4). existing scour protection can be classified as being in a Good, Fair/Poor, or Severe state depending on their Condition State.

- Scour Protection – Good/Fair: More than 80% of the scour protection has a Condition State (CS) of 1 and/or 2
- Scour Protection – Fair/Poor: More than 50% of the scour protection has a Condition State (CS) of 2 and/or 3
- Scour Protection – Poor/Severe: More than 50% of the scour protection has a Condition State (CS) of 4

*The absence of any scour protection warrants the highest score.

Scour Protection - Good | Scour Protection – Fair/Poor | Scour Protection – Poor/Severe

Figure 3.3.1.4 Scour Protection Condition States (CS) Example

Table 3.3.1.1 Existing Scour Protection Scores

EXISTING SCOUR PROTECTION							
Not Required	Sheet Pile Wall	Cofferdam	Riprap			Other	None
			Good	Fair/Poor	Poor/Severe		
0	0-3	0	1	3	4	1-3	5

b. Abutment Foundation

Classification scores are assigned to the different abutment configurations based on the shape of the abutment and the type of foundation. The classifying scores are intended to reflect the relative vulnerability of the different configurations.

In general, there are two shapes of abutments: Vertical Wall Abutments and Spill-Through Abutments. Record Plans should be reviewed, or field investigation can be made, to decide the foundation type. If the foundation configuration cannot be determined, it should be classified as unknown. A separate foundation configuration is provided for culverts.

1. Spill-Through Abutments (See Figure 3.3.1.5) have a sloped embankment leading up to the face of the abutment. The slope is usually protected with paving blocks or stone fill, though in some cases it may also be left unprotected. The sloped embankment of Spill-Through Abutments reduces both the depth and the velocity of the flow adjacent to the face and results in smaller scour depths.

2. Vertical Wall Abutments have no sloped embankment and essentially present a vertical wall adjacent to and at the same elevation as the stream channel. Because the full depth and velocity of the stream is adjacent to the face of a Vertical Wall Abutment, these are more vulnerable to scour than Spill-Through Abutments.

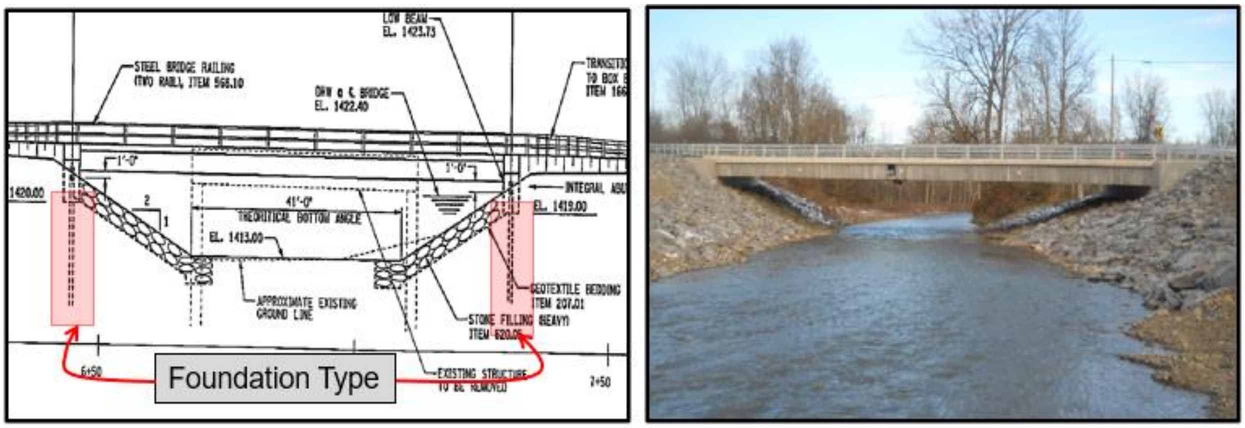
The different configurations are described below:

Spill-Through Abutments with footings on Long Steel or Concrete Piles or Spread Footings on Non-Erodible Bedrock. These configurations are the least vulnerable types. A non-erodible bedrock, such as Granite, has anticipated erosion or scour values that are measured in terms of centuries.

Spill-Through Abutments with footings on short piles, timber Piles or Spread Footings on erodible bedrock. short piles are more vulnerable than long piles because of the lessened embedment lengths and timber piles are prone to decay and damage making them more vulnerable than concrete or steel piles. An erodible bedrock, such as Shale, has anticipated erosion or scour values that are measured in terms of years. These foundations are more vulnerable than non-erodible bedrock.

Spill-Through Abutments with Spread Footings on Earth. Spread Footings on Earth are the most vulnerable footing type because there is only a soil foundation supporting them. Even though these abutments are on a slope away from the stream and are typically protected by stone fill, there is a possibility the slope could erode during a flood, exposing the footing.

Spill-Through Abutments with Unknown Foundations. These are assumed to be as vulnerable as a Spread Footing.



Spill-Through (Integral) Abutments

Figure 3.3.1.5 Spill-Through Abutments

Vertical Wall Abutments with footings on long steel or concrete piles or Spread Footings on non-erodible bedrock. Vertical Wall Abutments are generally considered more vulnerable than Spill-Through Abutments because the predicted scour depths are usually greater. However, the embedment length supplied by long piles, or the presence of a sound bedrock make these configurations less vulnerable than some of the spill-through configurations.

Vertical Wall Abutments with footings on long timber piles. This configuration is more vulnerable to scour damage because timber piles have a greater potential for decay and damage than steel or concrete piles.

Vertical Wall Abutments with footings on short piles of any material or Spread Footings on erodible bedrock. These configurations are more vulnerable than a foundation with long piles or with a non-erodible bedrock.

Vertical Wall Abutments with Spread Footings on Earth. Spread Footings on Earth are the most susceptible configuration and are therefore given the highest score. Spread footings are vulnerable because the worst-case scour depths will generally exceed the typical four-foot depth of a spread footing.

Vertical Wall Abutments with Unknown Footing types. These are assumed to be as vulnerable as spread footings.

The evaluating engineer should use judgment when assigning classification scores. For example, if there is extensive scour damage at a site, the score can be increased over the recommended one. Also, if a site has an abutment configuration which is not included in the flow chart, the engineer should assign a score which represents a similar vulnerability. Any changes should be documented for future reference.

Table 3.3.1.2 – Abutment Foundation Scores

ABUTMENT FOUNDATION SCORES									
A	B	C	D	E	F	G	H	I	J
Spill-Through				Vertical Wall					
Long Piles >20 ft Non-Erodible Rock	Short Piles <20 ft Timber Piles Erodible Rock	Spread On Earth	UNKNOWN	Long Piles >20 ft Non-Erodible Rock	Long Timber Piles >20 ft	Short Piles <20 ft Erodible Rock	Sheet Pile Wall With Unknown Length	Spread On Earth	UNKNOWN
0	2	3	3	0	3	5	7	10	10

c. Abutment Location on River Bend

An abutment located on the outside of a bend will experience higher velocities than one on the inside of the bend or one on a straight channel and is therefore more susceptible to scour damage (See Figure 3.3.1.6). Aerial photographs and field investigation can be used to determine this variable.

Figure 3.3.1.6 Abutment Location on River Bend

Table 3.3.1.3 Abutment Location on River Bend Scores

ABUTMENT LOCATION ON RIVER BEND		
Inside	Straight	Outside
0	0	2

d. Angle of Inclination

On skewed crossing, the angle of the approach embankment to the flow will affect the local scour depths at the abutment. An embankment angled upstream has more resistance, and hence scour potential to the floodplain flows returning to the stream channel than an embankment angled downstream. Due to historical reasons, the Angle of Inclination is defined as the angle of the downstream embankment with the stream for a straight stream with large overbanks, or 180º - A, where A is the upstream embankment angle with the stream (See Figure 3.3.1.7). For curved streams, the upstream flow tangent should be extended downstream for the angle with the embankment. The Angle of Inclination is shown below. Relative values are assigned to ranges of angles. If there is no overbank flow against an embankment that Angle of Inclination should be given the lowest score.

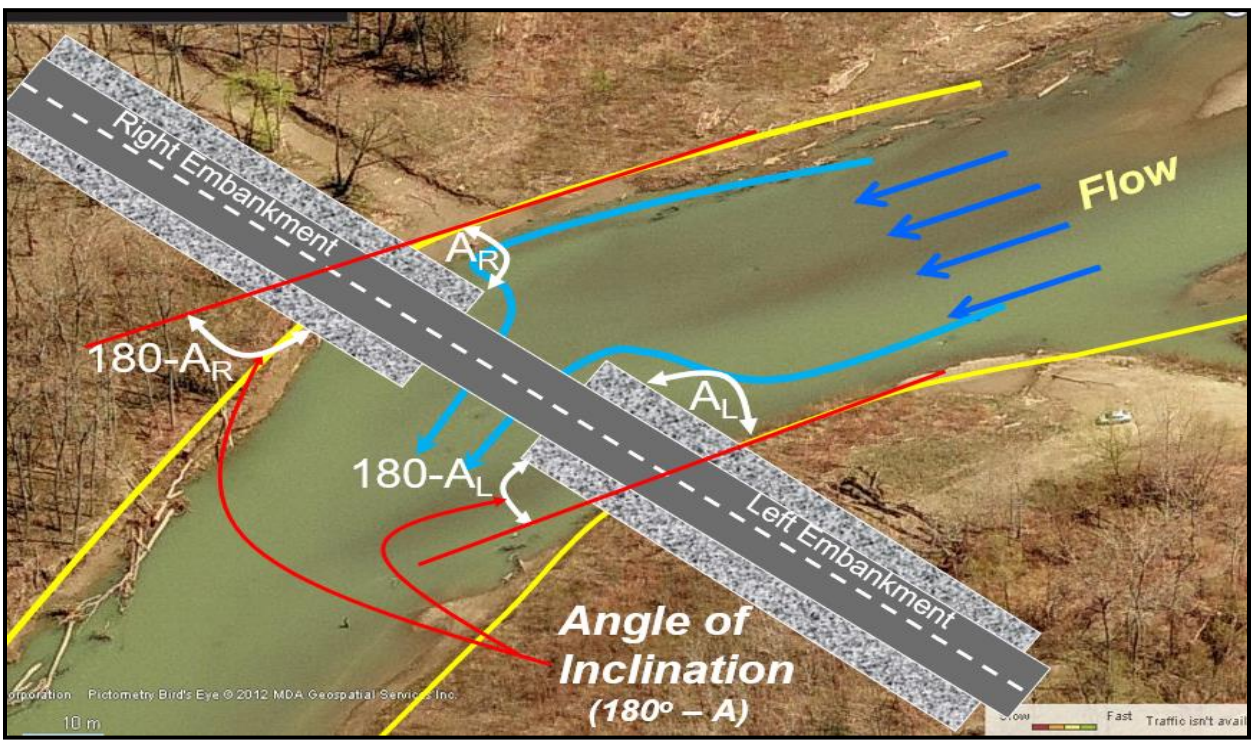


Figure 3.3.1.7 – Angle of Inclination

Table 3.3.1.4 Angle of Inclination Scores

ANGLE OF INCLINATION (180° – A°)			
0° - 20°	20° - 45°	45° - 90°	>90°
0	1	2	4

e. Embankment Encroachment

The encroachment of abutments and approach embankment into the floodplain is reflected in abutment scour equations and can affect the local and contraction scour depth at an Abutment. The intent of this parameter is not to identify sites where an approach embankment extends into a floodplain, but rather to identify situations where an embankment encroachment adversely impacts the total conveyance of the flood flows. For example, if the overbank flow at a bridge is only a small portion of the total flow and the flow that does exist is slow and shallow, then an encroachment into this area would not be considered significant. However, if the opposite were true and the volume of the overbank flow was a large portion of the total discharge and the velocities and depths were approaching the main channel values, then an encroachment into this area would be significant. (See Figure 3.3.1.8)

Scores are assigned for the following encroachments.

- Small – Impacts less than 10% of the total conveyance of peak discharge.
- Medium – Impacts between 10% and 25% of the total conveyance of peak discharge.
- Large – Impacts more than 25% of the total conveyance of peak discharge.

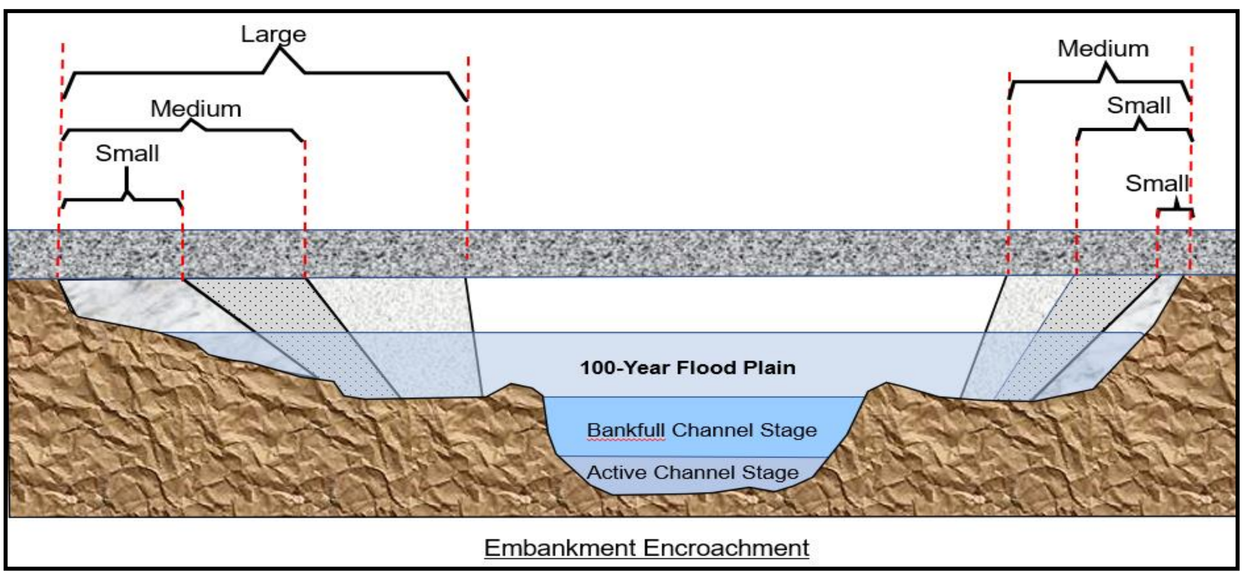


Figure 3.3.1.8 Embankment Encroachment

Lacking a detailed scour study at a site, the impact should be estimated considering the extent of encroachment onto the floodplain, historical information on overbank flow depths and discharges, the type and amount of vegetation on the banks and the topography of the site. Field Investigations, aerial photographs and FEMA Flood Insurance Rate Maps (FIRM) are sources from which this variable can be determined (See Figure 3.3.1.9).

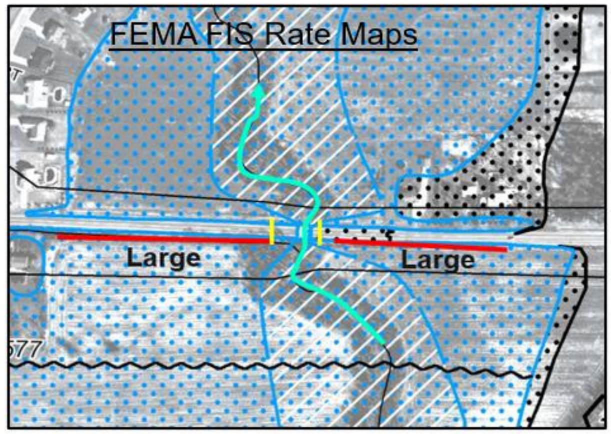


Figure 3.3.1.9 Embankment Encroachment with Aerial Photos and FEMA Maps

Table 3.3.1.5 Embankment Encroachment Scores

Embankment Encroachment		
Approximate Conveyance Restricted (%)		
< 10%	10% – 25%	> 25%
Small	Medium	Large
0	2	4

At the completion of the Abutment Assessment Section, the Classification Score for each abutment is subtotaled to determine which is the most critical (the highest) and this score is entered on the summary sheet (Form 3.3.1).

<u>For single span bridges with no piers, the higher abutment score is used as the Foundation Assessment Classification Score.</u> If the structure has been inventoried as a culvert, the culvert score typically controls. However, if this structure is supported on footings with natural streambed, then the classification process should follow the Bridge Foundation Assessment. For example, 3-sided structures such as con-span, hy-span, bebo arches, metal arches, etc. on footings with natural streambed, could be classified as such. This is added to the score from the General Hydraulics Section to yield the final Classification Score. Based on this classifying, a bridge should be placed into an appropriate Hydraulic Vulnerability Class

Document whenever it is decided to score and classify a culvert as having an abutment score. This is added to the score from the General Hydraulics Section to yield the final Classification Score. Based on this classifying, a bridge should be placed into an appropriate Hydraulic Vulnerability Class.

For Multi-Span Structures with piers, the classifying process is continued by proceeding to the Pier Assessment procedures. A final classifying score is determined for these structures by comparing the abutment and pier scores and selecting the most critical (highest score).

3.3.2 Pier Assessment

The pier classifying process is shown on Form 3.3.2. This section is intended to evaluate the relative vulnerability of a bridge to scour considering factors that affect pier scour. Form 3.3.2 will also be used to document the Pier Assessment process. A separate evaluation should be completed for each pier because the scour producing parameters may vary at each one. The piers are numbered sequentially from the left abutment, with the left side established looking downstream.

The parameters evaluated in the Pier Classifying process reflect their relative effect on scour. The rationale for their use follows:

a. Existing Scour Countermeasures

The rationale is the same as presented for the abutment assessment description.

Table 3.3.2.1 Existing Scour Countermeasures Scores (Pier)

EXISTING SCOUR PROTECTION - PIER							
Not Required	Sheet Pile Wall	Cofferdam	Rip Rap			Other	None
			Good	Fair	Poor		
0	0-3	0	1	3	4	1-3	5

b. Pier Foundation

Classifying scores are assigned to reflect the potential vulnerability of different types of pier foundations. The different configurations are described below, and the associated scores are shown in Table 3.3.2.2

- **Steel/Concrete Piles (including Caissons) -** These are the least vulnerable configurations. If the depth of reinforcement in concrete piles are not known, then it should be scored under C.

- **Spread Footings on Non-Erodible Bedrock -** This foundation is as sound as steel or concrete piles.

- **Concrete Piles Reinforced to an unknown depth below Streambed -** This type of foundation becomes very vulnerable if scour depths are below existing stream bed elevation. Unreinforced concrete piles are not very stable withstanding lateral forces from flowing water and/or debris pressure.
- **Timber Piles -** These are more vulnerable than steel or concrete piles because they are prone to decay and damage.

- **Spread Footings on Erodible Bedrock -** Spread footings are the most vulnerable footing type, but the presence of bedrock provides some reduction in vulnerability.

- **Spread Footings on Earth -** These are the most vulnerable foundation types.

- **Unknown Footing Types -** These are assumed to be as vulnerable as spread footings because the actual conditions which exist at these unknown sites could be as vulnerable to scour damage.

Table 3.3.2.2 Pier Foundation Scores

PIER FOUNDATION						
A	B	C	D	E	F	G
Steel Piles Concrete Piles* ≥ 20' with Reinforcement Below Calculated Scour Depth *Can use If < 20' and designed to resist scour	Spread On Non- Erodible Rock	Concrete Piles ≤ 20' with Reinforcement Above Calculated Scour Depth or Unknown Reinforcement Depth Below Streambed	Timber Piles	Spread on Erodible Rock	Spread on Earth	U N K N O W N
0	0	3	4	5	10	10

The evaluating engineer should use judgment when assigning classification scores. For example, if there is extensive scour damage at a site, the score can be increased over the recommended one. Also, if a site has a pier foundation which is not described here, the engineer should assign a score which represents a similar vulnerability. Any changes should be well documented for future reference. Record Plans should be reviewed to decide which pier foundation type exist at the structure.

c. Footing/Pile Bottom Below Streambed

This parameter reflects the relative susceptibility to scour based on the depth of the footing or pile bottom to the streambed elevation.

- Depths greater than 20 feet are arbitrarily assigned the lowest value.
- Depths less than 20 feet where the footing or piles are keyed into rock should be given the lowest score.
- Depths less than 20 feet warrant higher scores.
- The highest value is assigned to depths of 4 feet or less because this is the normal depth of Spread Footings.
- If conditions are unknown, then a depth of <4 feet should be assumed.

Inspection Reports and if available, Record Plans should/can be reviewed to determine the depth of footing or piles that is located below the stream bed.

Table 3.3.2.3 Footing/Pile Bottom Below Streambed Scores

FOOTING/PILE BELOW STREAMBED					
> 20 ft.	15-20 ft	10-15 ft	7-10 ft	4-7 ft	< 4 ft
0	1	2	3	4	5

Inspection Reports and if available, Record Plans should/can be reviewed to determine the depth of footing or piles that is located below the stream bed.

d. Pier Angle of Attack

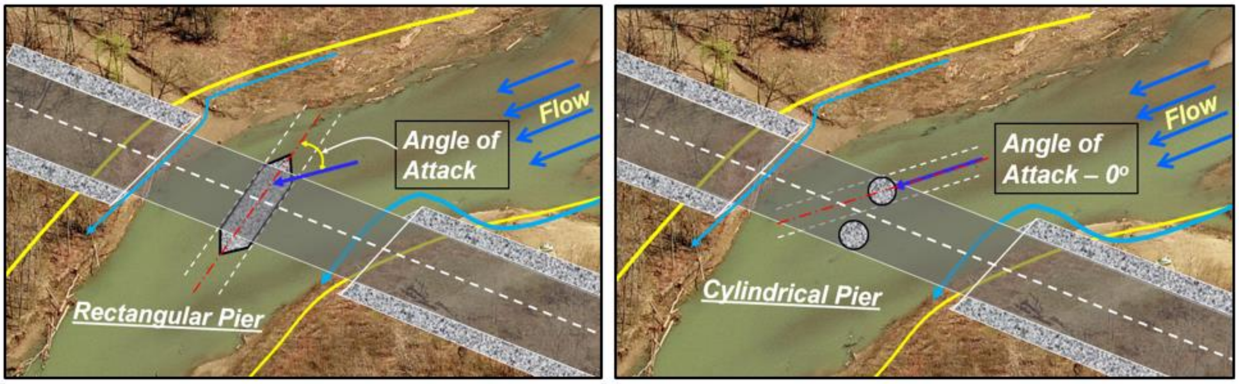


Figure 3.3.2.1 Pier Angle of Attack

The Angle of Attack of the flow on the pier is a key factor in the pier scour equation and can increase the predicted scour depths (See Figure 3.3.2.1).

The values assigned to each range of angles reflect the relative effect on scour potential. In situations where more than one Angle of Attack is possible, such as in a river confluence, the most conservative angle should be used.

Table 3.3.2.4 Pier Angle of Attack Scores

PIER ANGLE OF ATTACK (Degrees)			
0 or Cylindrical*	0° - 20°	20° - 45°	45° - 90°
0	2	3	4

*If a plinth is used to support circular columns, then the Pier should be considered a Solid Pier.

The following should be reviewed to determine the Angle of Attack on a Pier:

1. Aerial Photographs
2. Field Investigation
3. Bridge Inspection Reports

1. Aerial Photographs

Aerial photographs provide valuable information on Angle of Attack of stream flow on a pier (See Figure 3.3.2.2). If possible, the flood flow as it approaches the bridge should be considered when determining Pier Angle of Attack, especially for piers on the floodplain. The diagram below illustrates the Angle of Attack during high and normal flows.

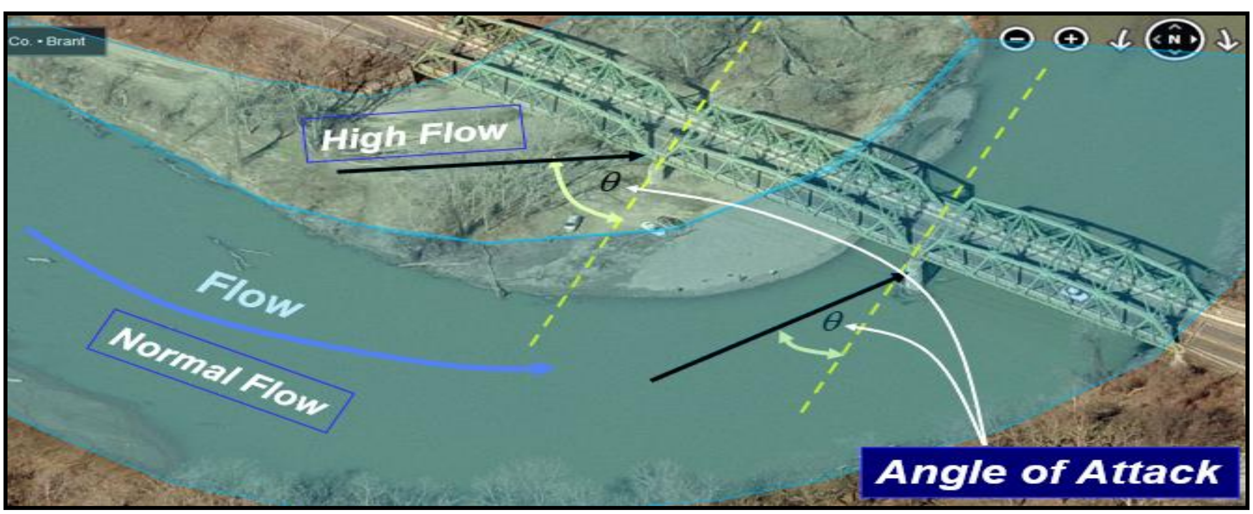


Figure 3.3.2.2 Pier Angle of Attack from Aerial Picture

2. Field Investigation

Field Investigation can also be used in determining Pier Angle of Attack, especially, if the investigation can be made during periods of high flows (See Figure 3.3.2.2).

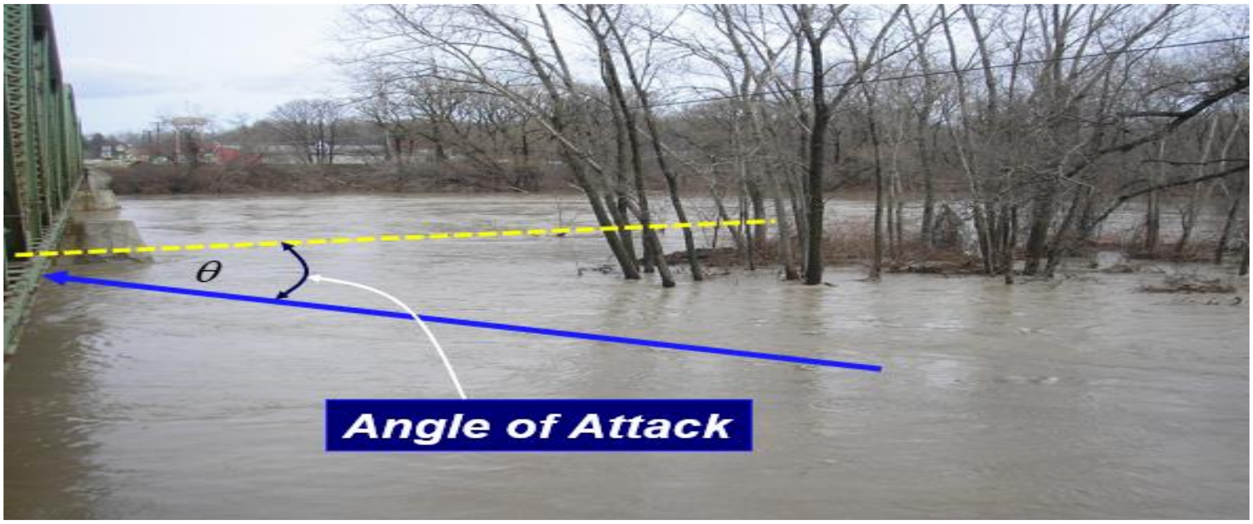


Figure 3.3.2.3 Pier Angle of Attack from Field Investigation

3. Bridge Inspection Reports

Bridge Inspection reports can be useful in determining the type of pier, high watermarks on embankment which can be used to determine high flows, and Angle of Attack on the Pier (See Figure 3.3.2.4).

Figure 3.3.2.4 Pier Angle of Attack from Inspection Reports

e. Pier Width

The pier width reflects the expected increase in local scour with increasing pier widths. The pier width is generally taken as the width of the plinth, stem or column extending above the streambed (See Figure 3.3.2.5). However, if the stream channel has degraded and the pier footing is exposed above the bottom of the streambed enough that it significantly obstructs the flood flows, then a weighted width of the pier footing and the plinth or stem should be used.

Classification scores are assigned for the ranges shown in Table 3.3.2.5. The 3 feet to 5 feet range represents the most common dimensions. The other ranges are arbitrarily assigned values up to a width of 10 feet.

No adjustment for debris or ice accumulation is used here because it is reflected in the General Hydraulics Assessment process.

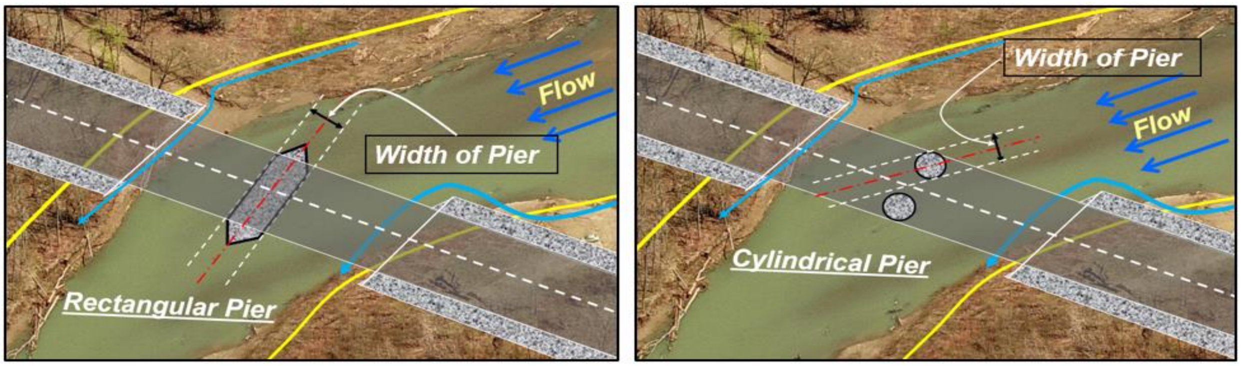


Figure 3.3.2.5 Pier Width

Table 3.3.2.5 Pier Width Scores

PIER WIDTH (ft)				
< 3	3-5	5-8	8-10	> 10
1	2	3	4	5

f. Simple Spans

This parameter recognizes that the ramifications of scour at multiple simply supported spans, such as for an elevated viaduct structure, are more severe than what would occur for continuous structures. Continuous structures are less likely to experience catastrophic failure due to the loss of some foundation material.

Table 3.3.2.6 Simple Span Scores

SIMPLE SPANS	
No	Yes
0	1

g. Multiple Piers in Floodplain

This parameter reflects the fact that a bridge with more than one pier in the floodplain presents a greater opportunity for scour damage to occur than a structure with just a single pier in the floodplain.

Table 3.3.2.7 Multiple Piers in Floodplain Scores

MULTIPLE PIERS IN FLOODPLAIN	
No	Yes
0	2

The Pier Classification Score is tabulated for each pier evaluated. The scores are summarized, and the most vulnerable pier (the highest score) is identified and entered on the summary sheet (Form 3.3.2).

<u>**The Pier Classification Score is compared to the Abutment Classification Score and the most critical (the highest score) is used as the Foundation Assessment Score. The Final Classification Score is determined by adding the Foundation Assessment Score to the General Hydraulic Score.**</u>

<u>**At the completion of the classifying process, bridges are placed into an appropriate Hydraulic Vulnerability Class using the ranges previously defined.**</u>

The Vulnerability Class and the Classification Score determine the priority for progressing to the Vulnerability Rating step. The bridge with the highest score in the HIGH Vulnerability Class would have the first priority followed in order by the remainder of the bridges in the HIGH class. A similar prioritization would apply to the MEDIUM and LOW Vulnerability Classes as well.

Flood-Watch and Post-Flood Inspection requirements should also be determined and implemented at this time.

3.4 Culvert Assessment

The purpose of the culvert assessment section is to evaluate Bridge-Sized Culverts, Frames and Arches vulnerability to hydraulic failures during storm events. A culvert is typically a hydraulic structure passing through embankment, where the minimum depth of fill is typically greater than 2 feet (See Figure 3.4.1). Failure would include any loss of fill around the structure that is necessary for the structural stability of the highway.

Culverts, Frames and Arches can be classified as Rigid or Flexible. concrete, masonry, or timber-type culverts are considered as rigid, whereas metal, plastic/polymer, are considered flexible. These types of structures can either be a closed conduit or three sided. They can be single or multiple-span structures.

Figure 3.4.1 Examples of Rigid and Flexible Culvert Type Structures

The structural stability of the highway and/or the culvert depends on the structure type. Figure 3.4.2 summarizes the importance of fill material around each structure type.

	FLEXIBLE	***RIGID***
1	Very limited flexural strength to carry live loads	Adequate flexural strength to carry live loads
2	Poor self-stability	Adequate self-stability
3	Backfill provides significant strength for the culvert	Backfill provides little additional strength For the culvert
4	Backfill required for stability of the ***culvert*** and the ***highway***	Backfill provides little additional stability for the culvert but necessary for the stability of the ***highway.***

Figure 3.4.2 Importance of Fill Material Around Flexible and Rigid Structures

Based on Figure 3.4.2, any condition that can lead to a loss of fill around a culvert structure during flood events (See Figure 3.4.3) should be assessed as a vulnerable condition for the highway at the stream crossing.

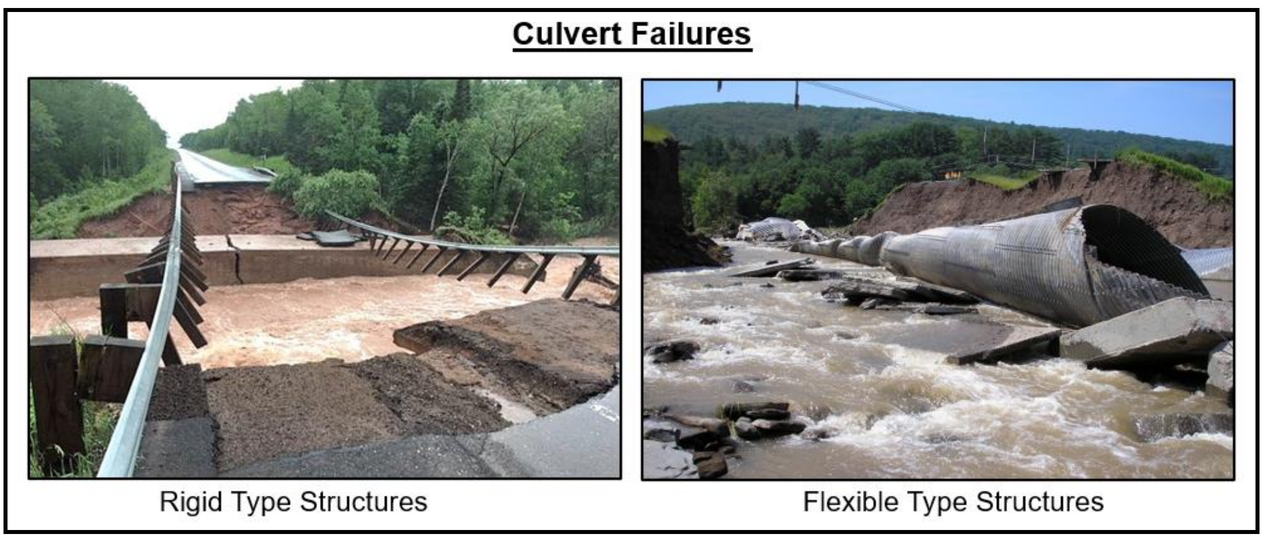


Figure 3.4.3 Failure Modes of Rigid vs. Flexible Type Structures Due to Loss of Fill

The parameters evaluated under the culvert assessment reflect their relative effect on promoting loss of fill around the structure during high flow events. Hence, the vulnerability of the structure to scour failure. The rational for their use are as follows:

a. Existing Scour Protection

i. ***Three-Sided Rigid or Flexible Structures:*** Existing scour protection on Three-Sided Rigid or Flexible Structure, should follow the same guidelines outlined in **Section 3.3.1 a. Existing Scour Protection at Bridge Abutment Foundation.**

ii. Four-Sided Rigid Structures or Closed Conduit Flexible Structures:
Four-Sided Rigid Structures and Closed Conduit Flexible Structures are mostly affected by scour at the outlet of the structure. As outlet scour develops, undermining of the structure and/or the cutoff wall can occur. Hence, failure of the culvert from the outlet end, which then progresses under the pavement. Figure 3.4.3 illustrates how outlet scour affects Four-Sided Rigid and Closed Conduit Flexible Structures.

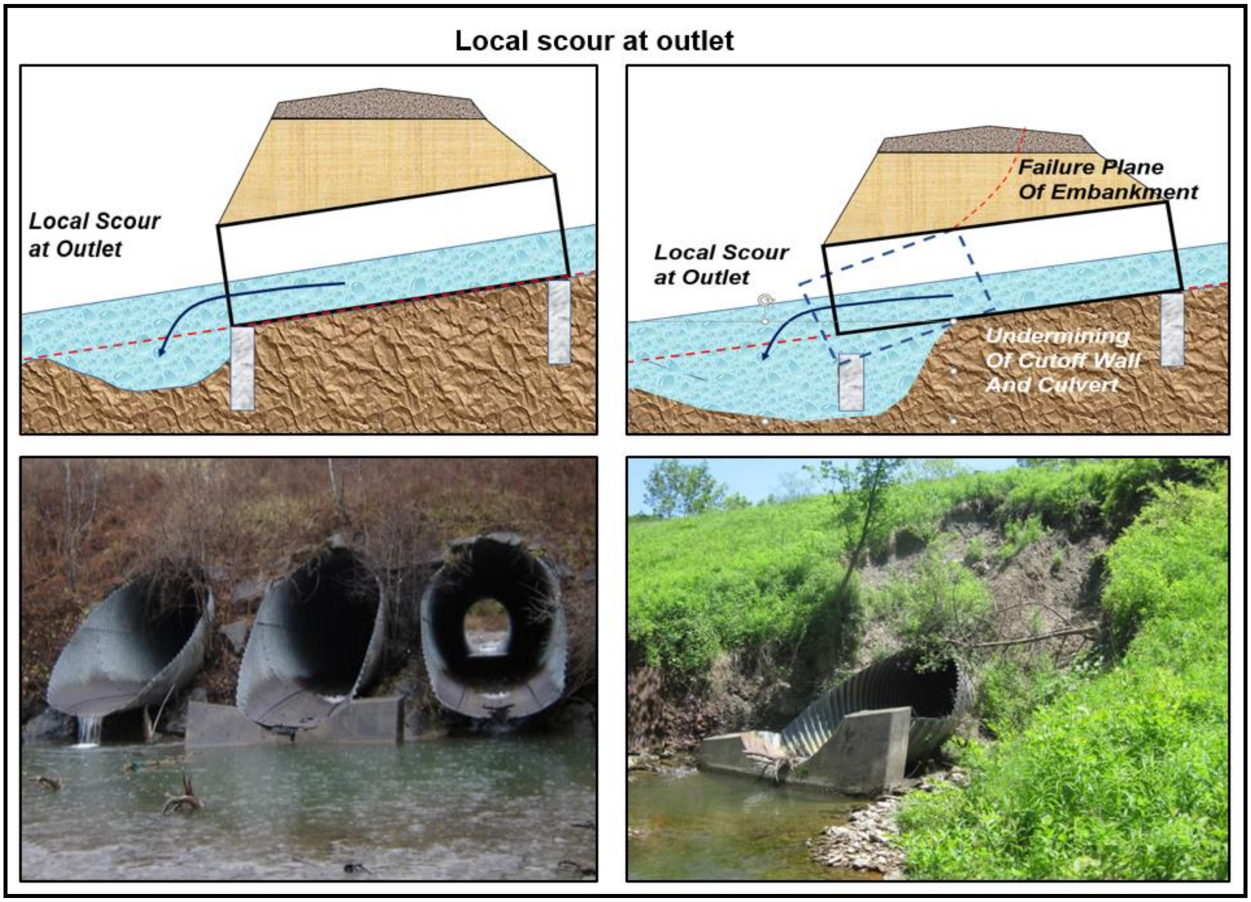


Figure 3.4.4 Illustration of Scour at Outlet - Rigid and Flexible Structures

The evaluation of this parameter should be based on existing scour protection at the inlet and outlet of the of the structure (See Figure 3.4.5 & 3.4.6). More emphasis should be placed on the outlet scour protection as that is where higher velocities are experienced. If a combination of a cutoff wall with riprap exists for outlet scour protection, the lowest score should be assigned.

Table 3.4.1 Existing Scour Protection Scores - Culvert

EXISTING SCOUR PROTECTION AT CLOSED CONDUIT CULVERT OUTLET									
Description	Not Required	Cutoff Wall (≥3.5 ft)			Riprap			Other	None
		<20% Exposed	20%-50% Exposed	> 50% or Undermined	Good	Fair	Poor		
Scores	0	0	3	5	1	3	4	1-2	5

Riprap Scour Protection and Cutoff Wall

Riprap-Failed, Cutoff Wall Undermined | Fair | Good

Figure 3.4.5 Examples of Scour Protection

Scour Protection

Other - Concrete Apron | None

Figure 3.4.6 Examples of Other Types of Scour or Non-Present

Field investigation and Bridge Inspection Reports together with a review of the Record Plans are a vital source of information when assigning scores for this parameter.

Bridge Inspection Reports: By reviewing the Condition State (CS) of scour protection at the inlet and outlet of the structure, a scour protection score can be assigned for this variable. A CS for scour protection of 1 or 2 indicates a *Good/Fair* scour protection, a CS of 3 would represent a scour protection that is in *Poor* condition, and a CS of 4 would represent that scour protection is in *Severe* condition or has failed completely. Refer to the NYSDOT Bridge Inspection Manual for all Condition State (CS) Definitions.

Records from Bridge Inspection Reports are illustrated in Figure 3.4.7. The CS for erosion and scour (ADE Item 800) is documented in the Element Assessment Summary Table and the Element Assessment by Span Table.

Element Quantities

Element Assessment Summary Table

Element	Total Quantity	Unit	CS-1	CS-2	CS-3	CS-4	CS-5
240 - Steel Culvert	86	ft			55	31	0
515 - Steel Protective Coating	6274	ft²	5764			510	0
800 - Erosion or Scour	48	ft	0	24		24	0
801 - Stream Hydraulics	1	each			1		0

Element Assessment by Span

Element**	Total Quantity	Unit	CS-1	CS-2	CS-3	CS-4	CS-5
Span Number : 1							
CO800 - Erosion or Scour	24	ft	0	12		12	0
240 - Steel Culvert	43	ft			43		0
515 - Steel Protective Coating	3137	ft²	2882			255	0
801 - Stream Hydraulics	1	each			1		0
Span Number : 2							
CO800 - Erosion or Scour	24	ft		12		12	0
240 - Steel Culvert	43	ft			12	31	0
515 - Steel Protective Coating	3137	ft²	2882			255	0

** Elements with a prefix designate the locations of BA-Begin Abutment, BW-Begin Wingwall, EA-End Abutment, EW-End Wingwall, CO-Culvert Outlet, and PR-Pier. No prefix generally indicates the element is part of the superstructure.

Figure 3.4.7 CS for Erosion and Scour (ADE Item 800)

b. Culvert Foundation

Classification scores are assigned to the different culvert configurations based on the type of the culvert and the type of foundation supporting it. The classifying scores are intended to reflect the relative vulnerability of the different configurations**.**

In general, there are four types of culverts: Three-Sided Rigid or Flexible and Four-Sided Rigid or Closed Conduit Flexible culverts. Record Plans should be reviewed, or field investigation can be made, to decide the foundation type. If the foundation configuration cannot be determined, it should be classified as unknown.

Three-Sided culverts have the same scour vulnerability as bridge abutments; however, the failure modes are slightly different. Scouring along the culvert foundation could lead to structural fill from around the culvert being removed by flood waters with potential collapse of the roadway (See Figure 3.4.8).

Stress failures on concrete footings supported on piles are less likely to occur when compared to spread footings on erodible soils. Flexible Culverts may fail more catastrophically than Rigid Culverts since flexible structure need the fill around the structure for their structural stability.

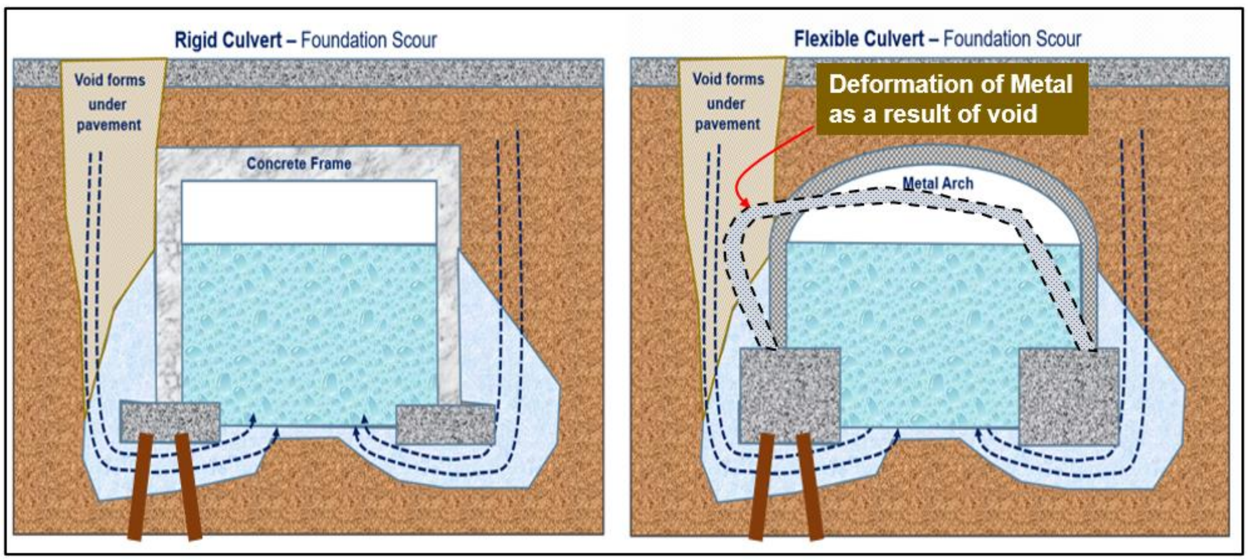


Figure 3.4.8 Illustration of Scour Affects Around Rigid and Flexible Structures.

Multiple cell structures have more ability to snag debris and promote sedimentation within the structure. As such, multiple cell structures are considered more vulnerable than single or larger openings.

The evaluating engineer should use judgment when assigning classification scores to culverts. For example, if there is extensive scour damage at a site, the score can be increased over the recommended one. Also, if a site has a unique foundation type that is not included in the flow chart, the engineer should assign a score which represents a similar vulnerability. Any changes should be documented for future reference. Table 3.4.b shows the relative scores for culvert foundation that should be used when making an assessment on their vulnerability.

Table 3.4.2 Foundation Type Scores - Culvert

CULVERT FOUNDATION									
A	B	C	D	E	F	G	H	I	J
RIGID STRUCTURES					FLEXIBLE STUCTURES				
3 -SIDED ON LONG PILES OR NON-ERODIBLE ROCK	3-SIDED ON SHORT PILES OR ERODIBLE ROCK	3-SIDED ON SPREAD FOOTING ON ERODIBLE SOIL OR UNKNOWN FOUNDATION	LARGE FOUR-SIDED STRUCTURE > 20 FEET	MULTIPLE SMALL BOX STRUCTURE EACH ≤ 10 FEET	3 -SIDED ARCH ON LONG PILES OR NON-ERODIBLE ROCK	3-SIDED ARCH ON SHORT PILES OR ERODIBLE ROCK	3-SIDED ARCH ON SPREAD FOOTING ON ERODIBLE SOIL OR UNKNOWN FOUNDATION	LARGE METAL BOX STRUCTURE OR PIPE > 20 FEET	MULTIPLE SMALL METAL BOX OR PIPE EACH < 10 FEET
0	2	3	0	4	4	5	7	6	8

c. Primary Member Condition State

The backfill around culverts is a key element for the stability of a highway. The loss of fill can comprise the solidity of the pavement. This can become more pronounced during flood events as the flowing water acts as a conveyance system removing structural fill from around the culverts, with an increased risk if the culvert is not structural sound in keeping the fill in place.

The Condition State of the Primary Element (Rigid or Flexible Structure) is good guidance to determine if the primary element is structurally sound to keep the fill around the culvert in place during flood events. Concrete deterioration can lead to conditions where there are voids in the concrete walls and/or ceiling where fill can escape into the flowing water. Metal culverts can deteriorate because of corrosion and abrasion to such an extent where there are perforations in the metal allowing material to escape from around the culvert.

Perforations at the invert of a flexible culvert can lead to hydrostatic forces building up beneath the invert which can cause "heaving" at the bottom of the culvert during flood events. These types of conditions would be classified as a CS 4 – Severe Condition of the primary element (See Figure 3.4.9). The quantity of CS 4 that exists in the primary element may influence how quickly a culvert and/or the pavement section may fail under flood conditions.

Figure 3.4.9 Culvert with Primary Element Rated CS 4

Table 3.4.3 Relative scores for culvert primary element condition states

PRIMARY ELEMENT CONDITION STATE				
100% CS 1-2	90% CS 3	LESS THAN 20% CS 4	20% - 50% CS 4	> 50% CS 4
0	1	3	4	5

Bridge Inspection Reports and/or field investigations are vital sources where the Condition State of the primary element can be derived (See Figure 3.4.10).

Element Quantities

Element Assessment Summary Table							
Element	Total Quantity	Unit	CS-1	CS-2	CS-3	CS-4	CS-5
240 - Steel Culvert	86	ft			55	31	0
515 - Steel Protective Coating	6274	ft^2	5764			510	0
800 - Erosion or Scour	48	ft	0	24		24	0
801 - Stream Hydraulics	1	each			1		0

Element Assessment by Span							
Element**	Total Quantity	Unit	CS-1	CS-2	CS-3	CS-4	CS-5
Span Number : 1							
CO800 - Erosion or Scour	24	ft	0	12		12	0
240 - Steel Culvert	43	ft			43		0
515 - Steel Protective Coating	3137	ft^2	2882			255	0
801 - Stream Hydraulics	1	each			1		0
Span Number : 2							
CO800 - Erosion or Scour	24	ft		12		12	0
240 - Steel Culvert	43	ft			12	31	0
515 - Steel Protective Coating	3137	ft^2	2882			255	0

** Elements with a prefix designate the locations of BA-Begin Abutment, BW-Begin Wingwall, EA-End Abutment, EW-End Wingwall, CO-Culvert Outlet, and PR-Pier. No prefix generally indicates the element is part of the superstructure.

Figure 3.4.10 CS for Primary Element – NBE Item 240

d. Angle of Attack:

The Angle of Attack the stream makes as it enters a culvert is defined at the angle between the longitudinal axis of the culvert and the stream flow (See Figure 3.4.11). The Angle of Attack influences how efficient a culvert can pass debris/sediment, minimize bank erosion and approach roadway failures. The larger the Angle of Attack, the culvert will have less ability to pass debris/sediment through the structure. It also enhances bank erosion that can lead to approach roadway failures.

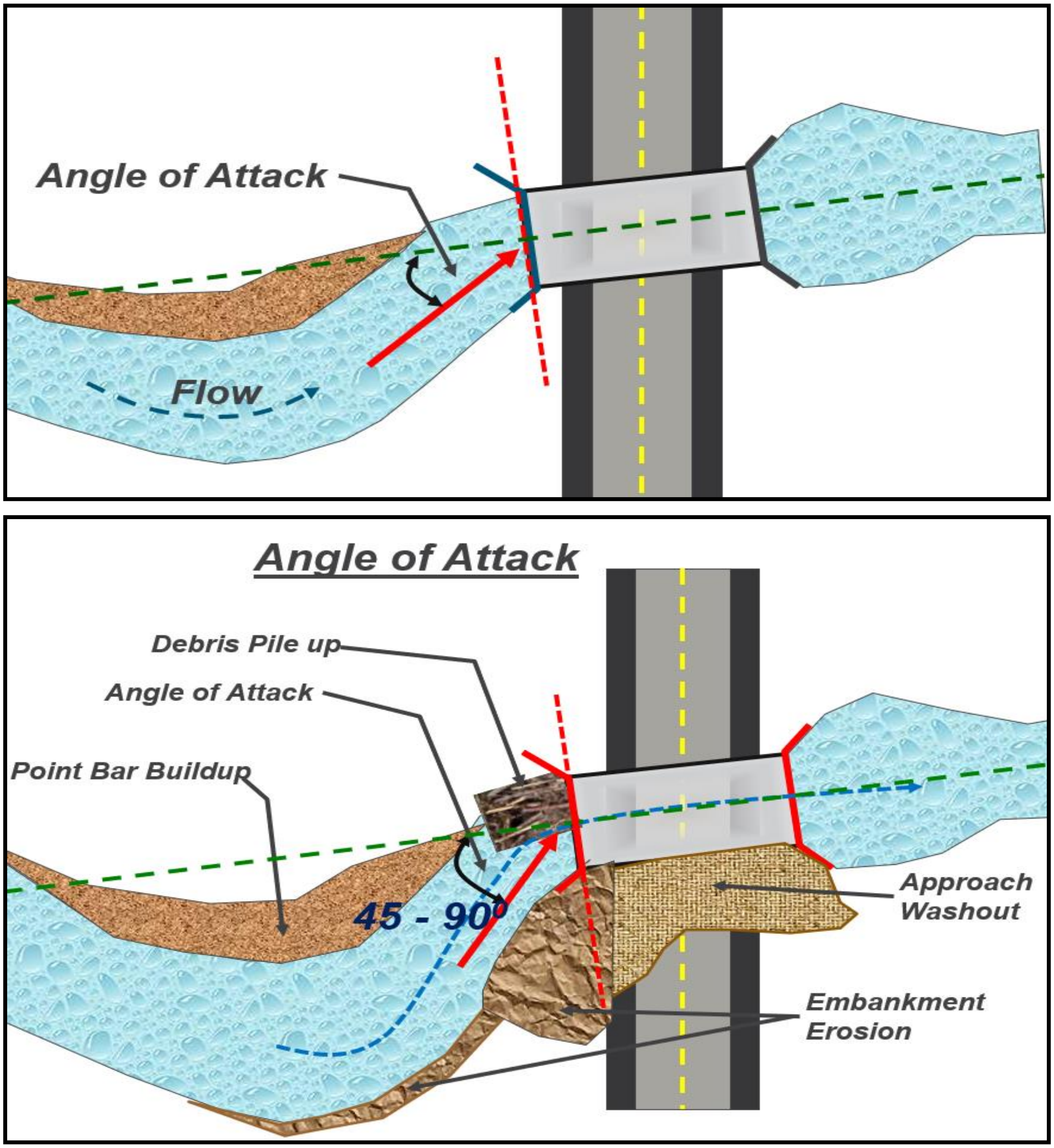


Figure 3.4.11 Stream Angle of Attack on a culvert

Table 3.4.4 Angle of Attack Scores – Culvert

ANGLE OF ATTACK (Degrees)				
Angle (Degrees)	0°	0°-20°	20°-45°	45°-90°
Scores	0	1	3	4-5

Field investigation, Bridge Inspection Reports, and aerial photographs (See Figure 3.4.12) can all be used in determining the Angle of Attack a stream makes as it approaches the inlet of a culvert.

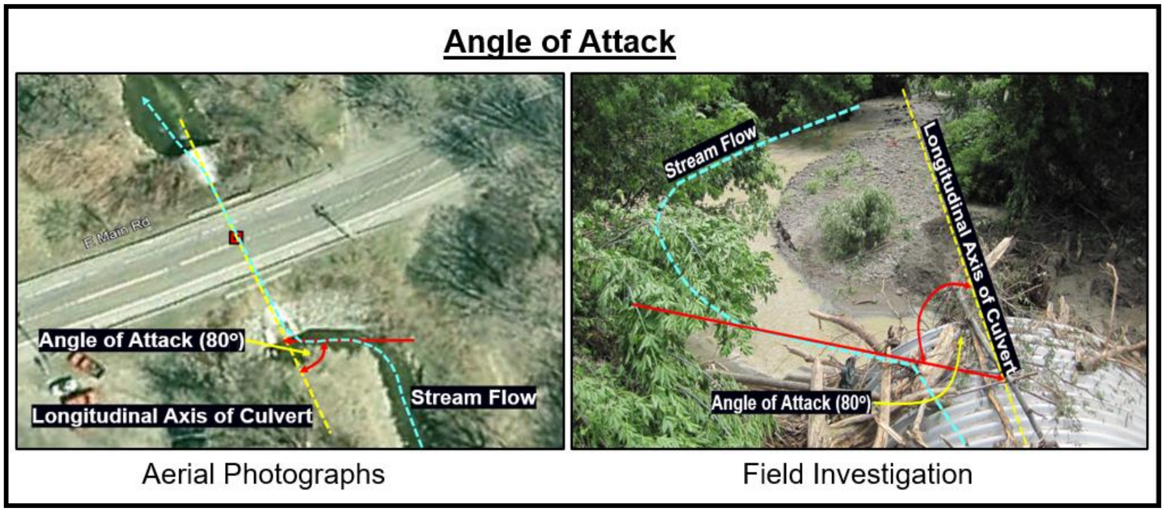


Figure 3.4.12 Angle of Attack from Aerial Photographs

e. Trapped Debris/Sediment

Trapped debris/sediment is a measure of the percentage of the waterway area that is reduced because of debris/sediment trapped *inside* the culvert, preventing flow from passing through the culvert (See Figure 3.4.13). It should not be confused with waterway opening, as that is a measure of the percentage of area blocked at the *inlet* of the structure restricting flow entering the culvert. In cases where the waterway opening is reduced and there is significant trapped debris/sediment in the culvert, can increase the risk in roadway overtopping, which can result in pavement/culvert failures.

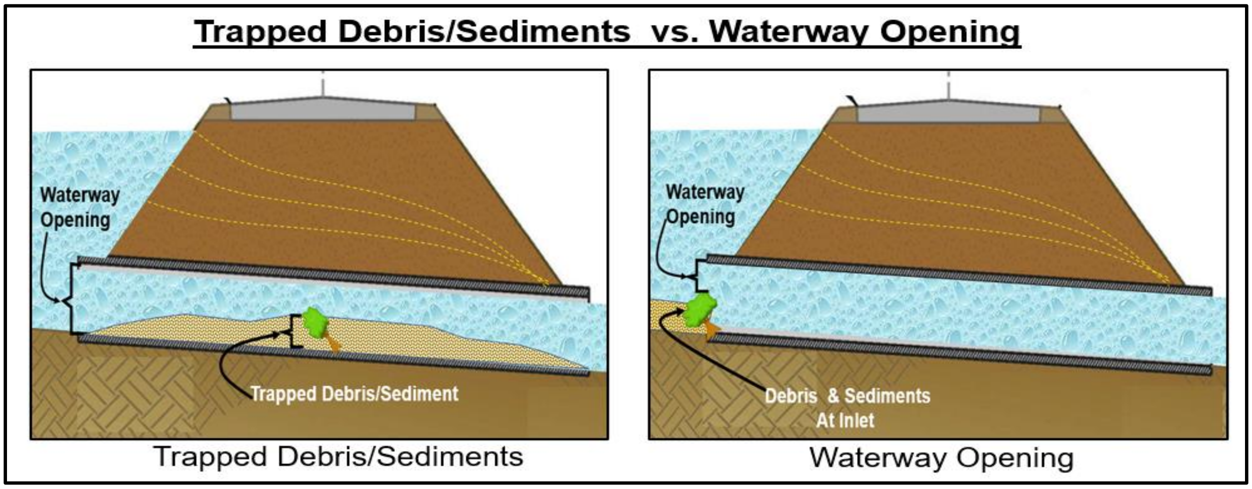


Figure 3.4.13 Trapped Debris/Sediments and Waterway Opening

Table 3.4.5 Trapped Debris/Sediments Scores – Culvert

TRAPPED DEBRIS/SEDIMENT SCORES		
Small	Medium	Large
< 20%	20% - 50%	> 50%
1	2-3	4-5

Bridge Inspection Reports and/or field investigation are vital sources where the trapped debris/sediments inside the culvert can be determined. Most Bridge Inspection Reports document waterway opening based on dropline readings at the inlet and outlet of culverts.

Contraction Scour can remove any sediment build up at the inlet of the culvert, thus showing a perfect waterway opening. These sediments can get deposited inside the culvert. However, a poor waterway opening reported in the Bridge Inspection Report, should not be mistaken for trapped debris/sediment inside the culvert. It can be an indication that there may be siltation in the culvert.

Bridge inspection photographs and/or field investigation can be used to verify the amount of sedimentation that exist within the culvert. Figure 3.4.14 illustrates an approximately 60% of waterway opening blocked by debris at the inlet versus only 20% of sediment trapped in Span 2 of structure.

Figure 3.4.14 Example of Trapped Debris/Sediments and Waterway Opening

SECTION 4 HYDRAULIC VULNERABILITY RATING

4.1 General

The Vulnerability Rating process is common to all six identified Bridge Safety Assurance (BSA) failure modes, and it is intended to provide a uniform measure of a structure's vulnerability to failure based on the likelihood of a failure occurring and the consequences of a failure.

There are six possible vulnerability ratings as shown in Table 4.1. The six ratings indicate the type of corrective actions needed to reduce the failure vulnerability of a bridge and the urgency in which these actions should be implemented. Definitions are found in Appendix A.

Table 4.1 VULNERABILITY RATING DESCRIPTIONS

RATING	DESCRIPTION
1	Safety Priority
2	Safety Program
3	Capital Program
4	Inspection Program
5	No Action
6	Not Applicable

For an overview of the rating process and a detailed description of each failure mode, see Section 4.2. Bridges may be rated without the use of these guidelines; however, complete documentation justifying the rating must be well documented in the Hydraulic Vulnerability Assessment.

4.2 Rating Procedures

The vulnerability rating process is similar to the classifying process in that, scores are assigned to evaluate the likelihood and consequence of a failure and then these rating scores are combined, as shown in equation (4.1), to determine the Vulnerability Rating Score.

$$\textbf{Vulnerability Rating Score} = \textbf{Likelihood Score} + \textbf{Consequence Score} \quad \textbf{(4.1)}$$

The vulnerability rating (1 through 6) is determined using the rating score ranges shown in Table 4.1. Overlapping ranges are provided to allow the evaluator some discretion in choosing the appropriate rating. A rating outside the recommended ranges may be used. However, complete documentation must be well documented in the Hydraulic Vulnerability Assessment.

Table 4.2 VULNERABILITY RATING SCORE RANGES

RATING	SCORING RANGE
1	> 15
2	13 - 16
3	9 - 14
4	< 15
5	< 9
6	---

In these instances, the Vulnerability Rating Score can be disregarded and a rating of 6 assigned to the structure. The likelihood and consequence scores are weighted equally in the rating equation. The likelihood score is determined using the results of the classifying process; the consequence score is determined on the basis of the type of failure which is anticipated and the public exposure to that failure.

Form 4.1 is used as a worksheet for completing the ratings and as a summary sheet for the results. Detailed descriptions of the criteria for evaluating the likelihood and consequence of a failure are found in Sections 4.2.1 and 4.2.2 respectively.

Bridges which are not vulnerable to a particular failure mode should be rated 6 for that mode. For instance, bridges not over water are not vulnerable to hydraulic failures, and similarly, concrete bridges are not vulnerable to the steel detail failures.

4.2.1 Likelihood of a Failure

The likelihood of failure score is determined using the results of the classifying process. If available, the results of a detailed engineering analysis may also be used to supplement the results of the classifying process. Table 4.3 provides scores which should be assigned to the different vulnerability categories.

The vulnerability classes (HIGH, MEDIUM, and LOW) are the same as previously defined in Table 3.1 of the classifying step. If there is no vulnerability to a particular failure mode, the Vulnerability Rating Score shall be zero. The likelihood score determined from Table 4.3 should be used when completing Form 4.1 to determine the vulnerability rating score.

Table 4.3 LIKELIHOOD OF FAILURE SCORES

VULNERABILITY CLASS	LIKELIHOOD SCORE
HIGH	10
MEDIUM	6
LOW	2
NOT VULNERABLE	0

4.2.2 Consequence of Failure

The consequence of failure is evaluated based on the type of failure the bridge is prone to and the exposure to the public that a failure would cause. The result of this evaluation will be a consequence score determined as shown in equation (4.2). This score is used when completing Form 4.1 to determine the vulnerability rating score.

$$\textbf{Consequence Score} = \textbf{Failure Type Score} + \textbf{Exposure Score} \qquad \textbf{(4.2)}$$

Descriptions of the failure type and exposure criteria evaluation procedures follow.

a. Failure Type

Failure type is a measure of the way in which a bridge fails. When evaluating this parameter, the actual vulnerability of a bridge to the specific failure mode is not considered and it is assumed that a failure has or will take place. The task of the rating engineer is to decide what the failure would look like. That is, will it be a sudden and complete collapse with potentially catastrophic consequences, or will it be a partial or localized failure that may or may not affect the serviceability of the structure.

Three failure types have been defined and are shown in Table 4.4.

Failures due to hydraulic forces generally will involve movement of the substructures, such as tilting of a pier or settlement of an abutment, which results in a loss of support or shifting of the superstructure. Impact or uplift damage to the superstructure caused by ice or debris buildup is another predominate cause of failures. To evaluate the type of failure a bridge is prone to, both the superstructure and the substructure configurations must be considered. For example, a simply supported, multi-girder bridge on high-column piers is prone to catastrophic failure caused by a shifting or tilting of the piers, whereas a continuous multi-girder bridge on the same pier(s) would be more apt to undergo a partial failure due to the loss of a pier. Additionally, an integrally constructed bridge, such as a rigid frame or concrete culvert, would generally be prone to settlements and shifting which may or may not result in structural damage.

Catastrophic: The structure is vulnerable to a sudden and complete collapse of a superstructure span or spans. This failure may be the result of a partial or total failure of either the superstructure or the substructure. A failure of this type would endanger the lives of those on or under the structure.

Structures vulnerable to catastrophic failure are, but not limited to:

1. Truss Bridges
2. Thru Girders
3. Simple supported multi-girder steel superstructures
4. Superstructures with Pin and Hanger support
5. Single and Multiple spans Flexible Structures – Metal Arches
6. Tall abutments and/or piers
7. Superstructures supported on high rocker bearings

Partial Collapse: The structure is vulnerable to major deformation or discontinuities of a span (which would result in loss of service to traffic on or under the bridge). This failure may be the result of tipping or tilting of the substructure causing deformations in the superstructure. A failure of this type may endanger the lives of some of those crossing or under the structure.

Structures vulnerable to partial collapse failure are, but not limited to:

1. Simple Span Reinforced Concrete Box Beams
2. Simple Span Reinforced Concrete I-Beams
3. Jack Arches
4. Superstructure supported on elastomeric bearings
5. Curved Steel Girders

Structural Damage: The structure is vulnerable to localized failures. This failure may be the result of excessive deformation or cracking in the primary superstructure or substructure members of the bridge. A failure of this type may be unnoticed by the traveling public but would require repair once it is discovered.

Structures vulnerable to this kind of structural failure are, but not limited to

1. Continuous Spans Reinforced Concrete Box Beams
2. Continuous Span Reinforced Concrete I-Beams

3. Single Span structure with Integral abutments
4. Single and Multiple spans Rigid Structures – Concrete Boxes, Arches and Frames

In some instances, it may be necessary to obtain additional assistance from experts in other fields, such as structural or geotechnical engineers.

Some factors which should be considered to evaluate the failure type are listed below. A combination of these and other factors will determine the potential failure type of a structure.

- Redundancy of the Superstructure
- Simple Span vs. Continuous Spans
- Bridge Type
- Span Length
- Support Conditions
- Abutments and Piers:
  - Type
  - Size
  - Height
  - Foundations
  - Bearing Types
  - Seat Widths

Rating scores are assigned for the different failure types, as shown in Table 4.4. These scores are used in equation (4.2) to determine the consequence of failure score.

Table 4.4 FAILURE TYPE RATING SCORES

FAILURE TYPE	SCORE
Catastrophic	5
Partial Collapse	3
Structural Damage	1

b. Exposure

The exposure parameter is a measure of the affect that a failure of a structure will have on the users of the bridge and the highway network. The exposure score is determined based on the traffic volume on the bridge and the functional classification of the highway carried by the bridge. The score is determined as shown in equation (4.3). This score is used to complete Form 4.1 to determine the vulnerability rating score.

$$\textbf{Exposure Score} = \textbf{Traffic Volume Score} + \textbf{Functional Classification Score} \quad \textbf{(4.3)}$$

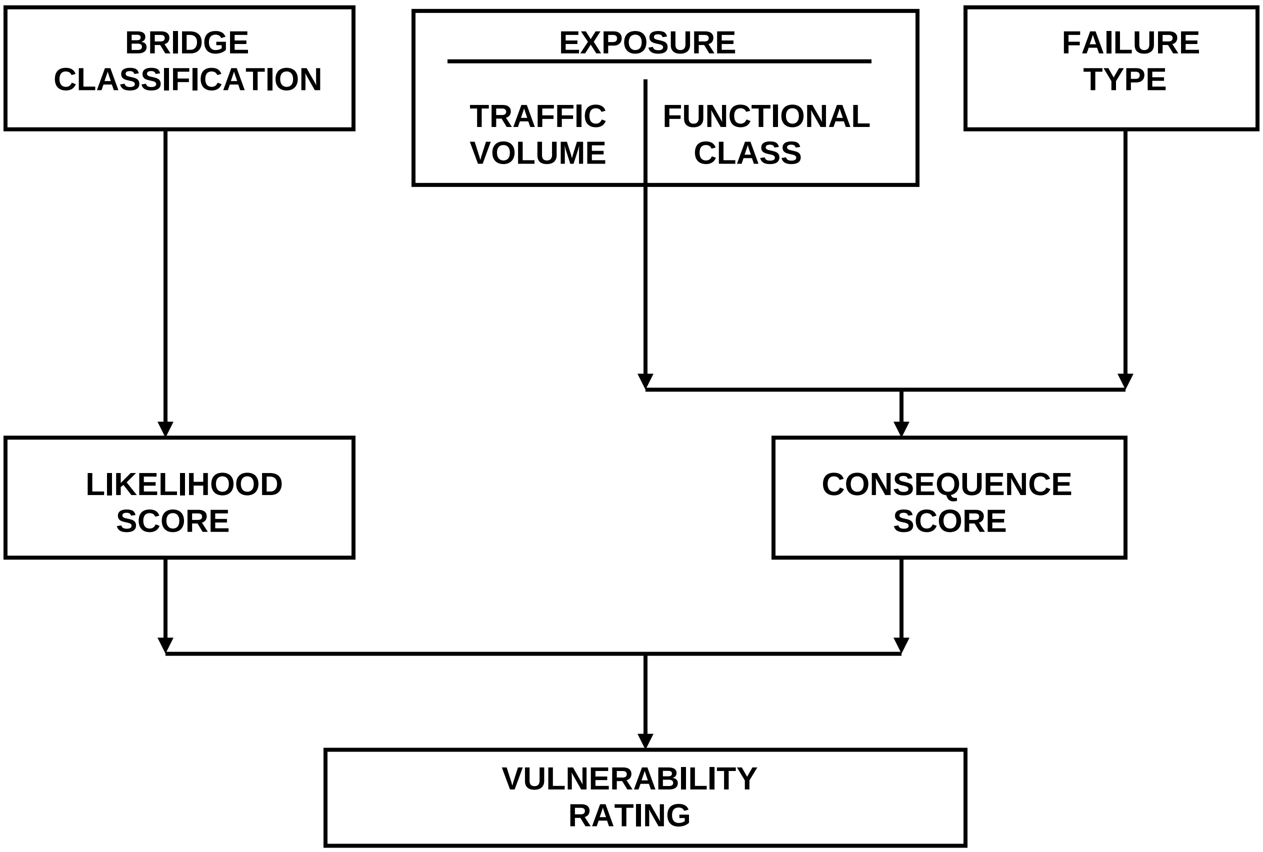
Rating scores for traffic and functional classification are assigned as shown in Table 4.5. These scores are used when completing Form 4.1.

Table 4.5 EXPOSURE RATING SCORES

Traffic Volume		Functional Classification	
AADT	Score	Classification	Score
> 25,000	2	Interstate & Freeway	3
4,000 – 25,000	1	Arterial	2
< 4,000	0	Collector	1
		Local Road & Below	0

The functional classifications are based on the definitions listed in the NYSDOT Bridge and Large Culvert Inventory Manual for the feature carried by the structure.

Figure 4.2 VULNERABILITY RATING PROCEDURE



Once all scores are complete, use Form 4.1 Vulnerability Rating Summary to complete the Hydraulic Vulnerability Rating for the Vulnerability Rating Procedure (See Figure 4.2).

At the completion of the Hydraulic Vulnerability Assessment, the evaluating engineer is required to enter their assessment scores and notes to the Bridge Data Information System (BDIS) within the Enterprise Asset Management System (EAM). Once the bridge is through Quality Control/Quality Assurance (QC/QA), the bridge will be updated and active in EAM. Once updated and active, the evaluating engineer should PDF the complete hydraulic inventory by selecting “Print Assessment to PDF”. This can be done by navigating the following path:

Structure Manager > Bridges & Culverts > Vulnerability > Hydraulic > Hydraulic – Active.

Once Download, the PDF should be saved to the Content Library in EAM by selecting “Add New Document to Library” In addition, the HVA Reassessment Request Form should be printed and signed by the evaluating engineer with any notes and acknowledging the HVA has been completed. Once signed, the HVA Reassessment Request Form should be saved to the Content Library.

SECTION 5 SCOUR CRITICAL RATING & PLAN OF ACTION

Catastrophic bridge failures resulting from scour led to the development and initiation of the *New York Bridge Scour Evaluation Program in 1988*. New York State has developed procedures to ensure each bridge over a waterway, whether existing or under design, was evaluated as to its vulnerability to scour in order to determine practical measures that can be taken for its protection and the safety of the travelling public. NYSDOT's initial approach to this program for existing bridges was published in 1995. The approach was recently reviewed and due to some inadequacies and limitations outlined in the previous manual, NYSDOT determined those evaluations were to be modified when conditions at the bridge necessitates a Hydraulic Vulnerability Reassessment as determined during the Bridge Inspection Process.

Therefore, the primary purpose of this section is to determine how these revised scour evaluation procedures are used to:

1. Assign a Scour Critical Rating (National Bridge Inventory (NBI) Item 113 Code) based on the bridge scour evaluation procedures outlined in Section 3 and 4 of this manual and using guidance in Appendix B – *NBI 113 Code/NYSDOT Additional Guidance*. Appendix B includes additional coding guidelines when assigning NBI 113 code 5. Note, NBI 113 code 5, sub-codes D, S and R, are NYSDOT sub-codes only and not found in FHWA guidance.

2. Develop and implement a Plan of Action (POA) based on the scour observation at the bridge.

5.1 Scour Critical Rating (NBI Item 113 Code)

The Scour Critical Rating (SCR) is a National Bridge Inventory Item (NBI). A single-digit code is used to identify the current status of the bridge regarding its vulnerability to scour. Guidance on conducting a scour evaluation is included in the FHWA Technical Advisory TA 5140.23 titled, "Evaluating Scour at Bridges." shown in (Appendix C). A description of the SCR codes is explained below:

Code	Description
N	Bridge not over waterway
U	Bridge with "unknown" foundation that has not been evaluated for scour. Until risk can be determined, a plan of action should be developed and implemented to reduce the risk to users from a bridge failure during and immediately after a flood event. See Hydraulic Engineering Circular No. 23 (HEC 23) for additional guidance.
T	Bridge over "tidal" waters that has not been evaluated for scour but considered low risk. Bridge will be monitored with regular inspection cycle and with appropriate underwater inspections until an evaluation is performed ("Unknown" foundations in "tidal" waters should be coded U.)
9	Bridge foundations (including piles) on dry land well above flood water elevations.
8	Bridge foundations determined to be stable for the assessed or calculated scour condition. Scour is determined to be above top of footing (Figure 5.1) by assessment. See Hydraulic Engineering Circular No. 18 (HEC 23) for additional guidance.

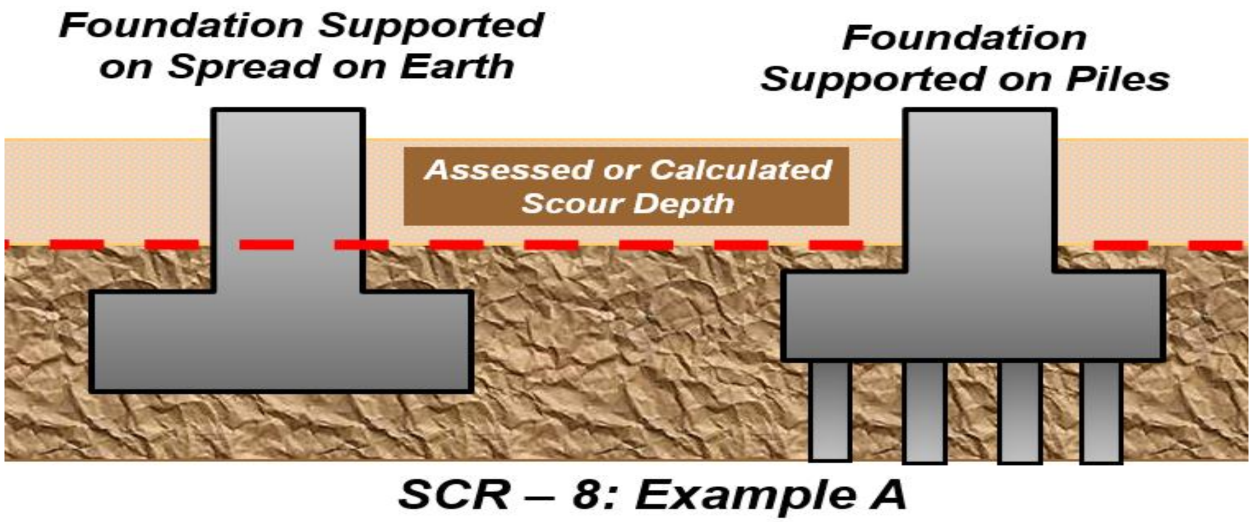


Figure 5.1 SCR 113 Code 8 Illustration

7 Countermeasures have been installed to mitigate an existing problem with scour and to reduce the risk of bridge failure during a single flood event. Instructions contained in a Plan of Action have been implemented to reduce the risk to users from a bridge failure during or immediately after a flood event. These instructions in the (POA) should include but not limited to Post-Flood Inspection and/or Periodic Scour Inspection to ensure the Scour Protections are still functional after the flood recedes.

6 Scour calculation/evaluation has not been made. (Use only to describe case where bridge has not yet been evaluated for scour potential.)

5 Bridge foundations determined to be stable for assessed or calculated scour condition. Scour is determined to be within the limits of footing or piles (Example B in Figure 5.3) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculations or by installation of properly designed countermeasures (see HEC 23).

NYSDOT has further defined Code 5 as 5D, 5S and 5R to describe Bridge Foundations (See Figure 5.2) as follows:

5**D** – A substructure unit that was **D**esigned to be stable after a design scour event (example a 100-year flood event). The foundation was designed to be below the calculated scour depth, or the foundations are supported on long piles that will be stable below the calculated scour depth.

5**S** – The bridge foundation was found to be unstable for assessed or calculated scour conditions. However, by the addition of a well-designed **S**cour countermeasure and/or **S**cour protection (see HEC 23), the foundations are assessed to be stable. The safety of the bridge during a storm event will depend on the condition of the installed scour countermeasure/protection during the life of the bridge.

5**R** – Bridge foundations are on **R**ock formations that have been determined to resist scour within the service life of the bridge.

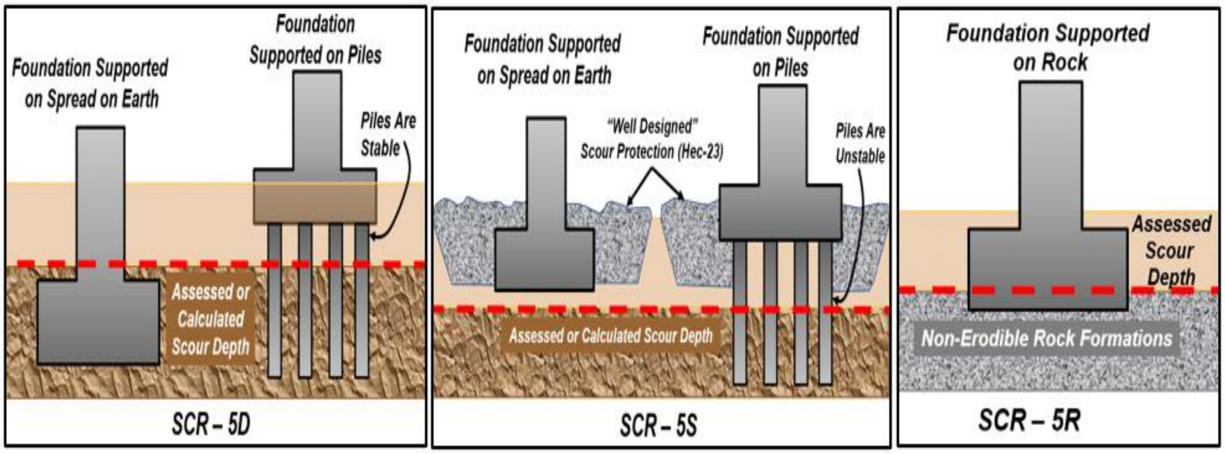


Figure 5.2 SCR 113 Code 5 Illustration

4 Bridge foundations determined to be stable for assessed or calculated scour conditions, field review indicates action is required to protect exposed foundations (See HEC 23).

3 Bridge is scour critical; bridge foundations determined to be unstable for assessed or calculated scour conditions (See Figure 5.3):

- Scour within limits of footing or piles. (Example B)
- Scour below spread-footing base or pile tips. (Example C)

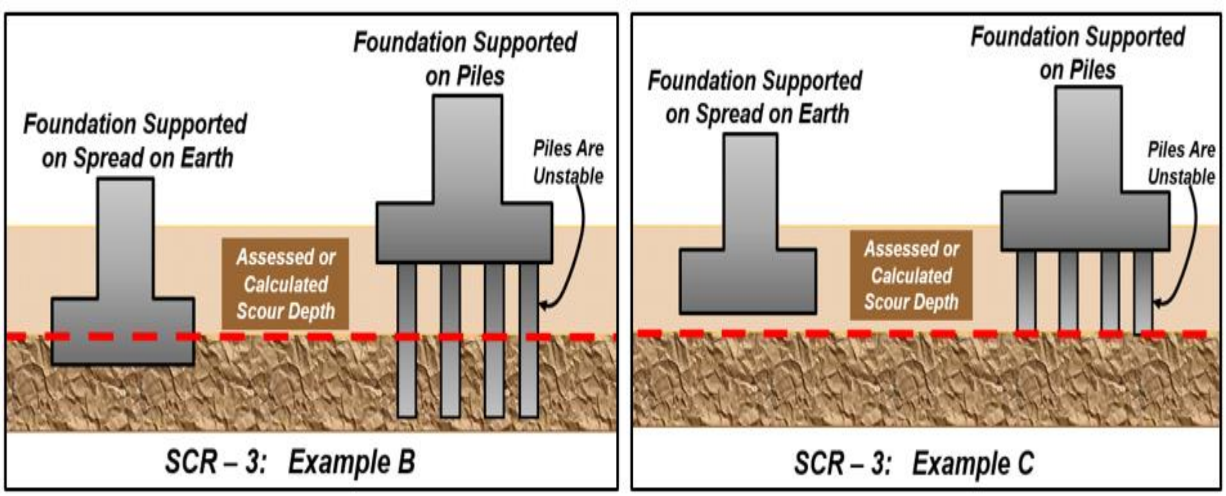


Figure 5.3 SCR 113 Code 3 (Scour Critical) Illustration

2 Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations, which are determined to be unstable by:

- a comparison of calculated scour and observed scour during the bridge inspection.
- an engineering evaluation of the observed scour condition reported by the bridge inspector for NBI Item 60 – Substructure (See Appendix F).

1 Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic. Failure is imminent based on:

- a comparison of calculated and observed scour during the bridge inspection.
- an engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60.

Note: Whenever a FHWA NBI 113 Item of 2 or below is assigned, the rating factor for NBI Item 60 - Substructure must be 2 and other affected items (i.e., load ratings, superstructure rating) shall be revised to be consistent with the severity of observed scour and resultant damage to the bridge.

0 Bridge is scour critical. Bridge has failed and is closed to traffic.

NYSDOT has adopted a policy where the Bridge Hydraulic Vulnerability Classification together with the scour observed at the bridge, are used to determine the SCR NBI Item 113 Code for the structure. This methodology depends on scour and stream channel defects documentation taken at the bridge during the General Bridge Inspection process and reported to the Hydraulic Engineer when conditions deem it necessary for a Hydraulic Vulnerability Assessment review. Additional guidance can be found in the NYSDOT Bridge Inspection Manual or current Technical Advisory.

5.1.1 Scour Critical Bridge

A Scour Critical Bridge is defined as a structure where one or more of its substructure units and/or its approaches, can become unstable due to hydraulic forces as a result of one or more of the following:

1. A Scour Assessment
2. A Scour Analysis and Evaluation
3. Physical observation of scour occurring at the structure.

Structures with Hydraulic Vulnerability Classification Class of High, or a Hydraulic Vulnerability Rating Score of 1 or 2 are considered scour critical. Structures with SCR NBI Item 113 Codes of 1, 2, 3, 7 or U are considered Scour Critical. A SCR NBI Item 113 Code 7 and U are not considered scour critical by the FHWA. However, NYSDOT considers Code 7 and U scour critical. Code 7 is assigned to structures where a Scour countermeasure/protection was installed to correct an immediate scour defect and should protect the bridge during a single storm event. However, the structure should be checked after every storm event to ensure the scour protection is still functional. It is advised by FHWA that a structure with a SCR Code of 7 should have a Plan of Action developed. NYSDOT requires a Plan of Action for bridges assigned SCR 7 and U.

5.2 Plan of Action (POA)

The National Bridge Inspection Standards (NBIS) regulation, 23 CFR 650.313.e.3, requires State DOTs to prepare a Plan of Action (POA) to monitor known and potential deficiencies and to address critical findings for bridges identified as Scour Critical. A POA shall be developed by bridge owners for all scour critical bridges. Generally, these are bridges with a Federal Highway Administration (FHWA) National Bridge Inventory (NBI) Item 113 less than 4, or equal to 7 or U. Although Code 7 and U are not considered Scour Critical by Federal Highway Administration (FHWA), NYSDOT considers them as such and requires a Plan of Action. The POA for an individual bridge contains a schedule for the timely implementation of a specific plan for the bridge. Some things to consider when developing the POA should include: Scour Countermeasures, interim Flood-Watch and/or Post-Flood Inspections to monitor the bridge's performance. In extreme cases, closing the bridge may be the only option until repairs and/or replacement can be completed. See Appendix D for a sample POA.

A POA should contain but not limited to the following information:

5.2.1 General Information

The General Information on a bridge should include:

A. Bridge Identification Number (BIN)
B. Feature Carried – Roadway, Reference Marker Number
C. Waterway Crossed – Name of Waterway
D. Waterway Type – Riverine, Tidal, Lake, Reservoir etc.
E. Location – Region, City, Village, County, State
F. Abutment Type – Spread on Earth, Spread on Rock, Pile Foundation, etc.
G. Pier Foundation Type -- Spread on Earth, Spread on Rock, Pile Foundation, etc.
H. Number of Spans
I. Continuous over Pier
J. Redundancy
K. Streambed Material
L. Critical Structure
M. Year Built.
N. Annual Average Daily Traffic (AADT)

5.2.2 Scour Vulnerability

The Scour Vulnerability for each bridge should include:

A. NYSDOT HVA Class – High, Medium, Low
B. NYSDOT HVA Rating Score – 1 through 5
C. SCR NBI Item 113 Code
D. Source of Item 113 Code – Assessment, Calculation, Scour observation

5.2.3 Responsibility for the POA

The person responsible for the POA should include:

A. Authors of the POA - name, title, agency/organization, telephone, email
B. Date
C. Concurrences on POA - name, title, agency/organization, telephone, email

5.2.4 Recommended Actions

The recommended action should include:

A. Increased Inspection Frequency:
B. Fixed Monitoring Device(s)
C. Flood Monitoring Program
D. Hydraulic/Structural Countermeasures

5.2.5 Detour Routes

The Detour route should include:

A. Detour route description (route number, from/to, distance from bridge, etc.)
B. Detour Map
C. Any Bridge or Culvert on the detour route with Posted Load or Vertical Clearance

Completed POA's for state owned and maintained Scour Critical Bridges are to be kept with the Bridge Inspection Records and should be available whenever their implementation is required.

Completed POA's for locally owned and maintained Scour Critical Bridges are to be kept with their bridge records and should be available when needed.

Upon request, the NYSDOT only requires a POA certification from the local bridge owner, certifying that a POA has been completed.

SECTION 6 FLOODWATCH PROGRAM

6.1 General

The **Flood-Watch Program** was established with the issuance of The New York State Bridge Flood Warning Action Plan (BFWAP) for state-owned or maintained Bridges (Appendix E). Guidance for The Flood-Watch Program is available to locally owned or maintained bridge owners. The goal of this program is to ensure that bridges with a high susceptibility to failure from hydraulic forces are monitored during periods of major flooding. The BFWAP calls for continual or periodic monitoring of bridges during periods of Flood Warning or Flash Flood Warning as issued by the National Weather Service (NWS) or New York State Emergency Management Office (SEMO). Bridges that are placed in High Risk-Flood category receive continuous monitoring and bridges that are placed in a Moderate Flood-Risk category receive periodic monitoring.

The criteria for placing bridges on the Flood-Watch List are listed in Section 6.2. These criteria are based on the results of the Hydraulic Vulnerability Assessment procedures contained in this manual and different criterion are applied after each step in the assessment process.

In some cases, bridges which should be on the Flood-Watch List are at the discretion of the Regional Structures Management Engineer as recommended by the Regional Hydraulics Engineer. Regional experience and knowledge of flood history, maintenance problems and records of repairs are some of the reasons a bridge may be included on the Flood-Watch list. See Section 6.2.2.

The decision on whether a bridge belongs in the High Flood-Risk or Moderate Flood-Risk category is based on the potential the structure has for sudden and catastrophic collapse. The vulnerability of a bridge to hydraulic forces is not considered in the determination of the risk category. In fact, it is assumed that the bridge will fail. Section 6.3 provides guidelines for determining the appropriate risk category. These guidelines are used only after it has been established that a structure needs to be included on the Flood-Watch List.

6.2 Selection Criteria

Criteria for deciding if a bridge belongs on the Flood-Watch List is based on Hydraulic Vulnerability Classification, Hydraulic Vulnerability Rating, Hydraulic Analysis or Other Hydraulic Vulnerabilities. All four criteria are discussed below.

6.2.1 Hydraulic Vulnerability Classifying

The Hydraulic Vulnerability Classification should be used for the Floodwatch List as follows:

- **HIGH** – Bridges in the HIGH Vulnerability Class shall be placed on the Flood-Watch List. Bridges with a HIGH Vulnerability Class can be excluded at the discretion of the Regional Structures Management Engineer, as recommended by the Regional Hydraulics Engineer. Whenever it is decided to not include a bridge on the Flood-Watch List with a High Hydraulic Vulnerability Classification, the rationale used to exclude it shall be documented in the Hydraulic Vulnerability Assessment for future reference.

- **MEDIUM** – Bridges in the MEDIUM Vulnerability Class can be placed on the Flood-Watch List at the discretion of the Regional Structures Management Engineer, as recommended by the Regional Hydraulics Engineer or as determined by the FHWA NBI113 Scour Critical Code. A history of flooding or debris or ice damage to the structure are some of the factors which should be considered in making a decision to place a bridge in this category on the Flood-Watch List. When it is decided to place a bridge on the Flood-Watch List with a Medium Hydraulic Vulnerability Classification, the rationale for including it shall be documented in the Hydraulic Vulnerability Assessment for future reference.

- **LOW** – Bridges in the LOW Vulnerability Class should not be included on the Flood-Watch List.

a. Hydraulic Vulnerability Rating

The Hydraulic Vulnerability Rating should be used in determining if a bridge belongs on the Flood-Watch List as follows:

- Bridges which have a Hydraulic Vulnerability Rating of 1 or 2 shall be placed on the Flood-Watch List.

- Bridges which have a Hydraulic Vulnerability Rating of 3 or 4 can be placed on the Flood-Watch List at the discretion of the Regional Structures

Management Engineer, as recommended by the Regional Hydraulics Engineer. If it is decided to include a bridge on the Flood-Watch List with a Hydraulic Vulnerability Rating of 3 or 4, the rationale used to include it shall be documented in the Hydraulic Vulnerability Assessment for future reference

- Bridges with a Hydraulic Vulnerability Rating of 5 should not be placed on the Flood-Watch List.

b. Hydraulic Analysis

Where the results of a detailed Hydraulic Analysis show a clear risk to either the abutments, piers or culvert, due to a 100-year design flood or less, the structure should be placed on the Flood-Watch List. The Detailed Hydraulic Analysis should consider the effects of installed scour protective countermeasures and foundation types. Whenever it is decided not to include a bridge on the Flood-Watch List with clear risk to either abutment, pier(s) or culvert, the rationale used to exclude it shall be documented in the Hydraulic Vulnerability Assessment for future reference

6.2.2 Other Hydraulic Vulnerabilities

Some bridges may belong on the Flood-Watch List for Hydraulic Vulnerability reasons which are non-scour related. Regional experience and knowledge of flood history, maintenance problems and records of repairs are the primary means available to identify these bridges. Some examples are listed below.

a. Bridges flagged by inspectors for damage to scour protection which are not yet repaired. Red flags shall always be placed on the Flood-Watch List if the bridge remains open, until the repairs are made. Yellow flags can be placed on the Flood-Watch list at the discretion of the Regional Structures Management Engineer, as recommended by the Regional Hydraulic Engineer. For locally owned or maintained bridges, an update to the Hydraulic Vulnerability Assessment should be completed to verify and/or update the current FHWA NBI 113, Scour Critical Rating (SCR). If the SCR is reduced to 3 or less or 7, a Plan of Action (POA) is required.

b. Bridges subject to failure due to inundation or overtopping by flood waters. Bridges with light superstructures not positively tied to their substructures are of special concern for this vulnerability.

c. Bridges subject to failure or damage from debris or ice forces.

d. Bridge with a history of or vulnerability to roadway approaches washing out.

e. Temporary structures shall have a Hydraulic Vulnerability Assessment and treated like any other in-service structure.

f. Temporary structures within a construction zone are the responsibility of the contractor and not considered in this manual.

g. Any bridge, at regional discretion, if reasons exist and adequate justification can be provided.

Any bridge added to the Flood-Watch List from these bullets or from regional experience shall be documented in the Hydraulic Vulnerability Assessment for future reference.

6.3 Flood-Watch Risk Categories

These guidelines are used to place a bridge into an appropriate Flood-Watch Risk Category. These guidelines are used only after it has been established that a structure needs to be included on the Flood-Watch List. The vulnerability of the bridge from hydraulic forces is not considered in the determination of the risk category. Official Flood-Watch Lists are found and maintained in Bridge Data Information System (BDIS).

6.3.1 High Flood-Risk Category

Bridges in the High-Flood Risk Category shall be monitored FULL-TIME once a Critical Condition is met, see BFWAP (2) for Critical Condition guidance. The FULL-TIME watch shall continue until the Flood Warning or Flash Flood Warning is terminated or at the discretion of the Regional Structures Management Engineer or Regional Bridge Maintenance Engineer. Bridges in this category have superstructure or substructure types which have a potential for sudden or catastrophic collapse.

Factors such as the redundancy and the continuity of the superstructure, the type of substructure units and the substructure foundation configurations should be considered when judging the potential for collapse. Some of the factors and bridge types which might be considered HIGH Flood-Risk are listed below. Combinations of these and other factors should be considered to determine the collapse potential of a structure.

- Non-redundant superstructures
- Two or three-girder bridges
- Multi-span, simply supported bridges

- Bridges with high, non-solid piers
- Bridges with single column piers
- Bridges with short bridge seats
- Bridges with spread footings
- Bridges with no positive tie downs
- Metal Culverts with a Primary Element Rating of 4 or any other criteria set forth by the Regional Hydraulics Engineer or in the BFWAP

6.3.2 Moderate Flood-Risk Category

Bridges in this category have superstructure and substructure types that are less prone to sudden collapse but are prone to more gradual settlement or sagging failures. These bridges should receive intermittent monitoring during a Flood Warning or Flash Flood Warning event. Bridges in the Moderate Flood-Risk Category should be monitored on an intermittent basis unless a Critical Item is found, see BFWAP for Critical Item guidance (2). If a Critical Item is found, a full-time watch, or an immediate closure will be required. Considering such factors as: scour susceptibility, type of construction, peak flow, accumulation of debris or ice or any other pertinent reason. Some factors and bridge types which might be considered Moderate Flood-Risk are listed below. Combinations of these and other factors should be considered to determine the collapse potential of a structure.

- Bridges with redundant superstructures
- Multi-span continuous bridges
- Bridges with low height solid piers or abutments
- Bridges with integral abutments
- Culverts with a history of overtopping or debris accumulation or high Primary Element Rating or any criteria set forth by the Regional Hydraulics Engineer or in the BFWAP
- Rigid frames
- Single span bridges or bridges which are vulnerable due to a failure of the abutments
- Bridges with piles

6.4 Inspection Procedures

The New York State Bridge Flood Warning Action Plan for State Bridges (Appendix E) provides specific details on how the Flood-Watch Program is implemented and includes guidelines on what the field teams should look for at the bridge site(s). The field teams, however, are often made up of personnel from the Bridge Maintenance Department or Highway Residencies who will have no specific training in bridge hydraulic principles. To assure that the appropriate items are being observed, the Regional Hydraulics Engineer should periodically review monitoring procedures with this staff.

Any time a Flood Warning or Flash Flood Warning is issued by the National Weather Service for drainage areas that include Flood-Watch Bridges, Flood-Watch patrols shall be activated. While patrolling, personnel should be completing the Bridge Flood Warning Report (Form 6.1) or the Metal Culvert Flood Warning Report (Form 6.1). Once the Flood Warning or Flash Flood Warning has been canceled or terminated by the National Weather Service, Regional Structures Management Engineer or Bridge Maintenance Engineer, reports should be transmitted to the Regional Hydraulics Engineer.

Any bridge on the Flood-Watch List shall be on the Post-Flood Inspection List. The Post-Flood Inspection procedure is implemented to ensure that no new damage has occurred following any major flood event. Guidance on the Post-Flood Inspection Program can be found in Section 7 of this manual and is available to locally owned or maintained bridge owners.

SECTION 7 POST-FLOOD INSPECTIONS

7.1 General

The purpose of the **Post-Flood Inspection** program is to inspect State-Owned Bridges on the Flood-Watch List or the Post-Flood Inspection List for damage following a major flood event. This guidance on The Post-Flood Inspection Program is available to locally owned or maintained bridge owners. These inspections are necessary after major floods to determine if there has been any new damage or undermining to the bridge. If damage has occurred that warrants repair, the observed conditions should be flagged, and appropriate actions should be implemented.

7.2 Selection Criteria

Structures which meet any of the following criteria should be included on the Post-Flood Inspection List.

- All bridges on the Flood-Watch List. Any bridge on the Flood-Watch List shall be on the Post-Flood Inspection List.

- Bridges with a Scour Critical Rating (SCR) of 2, 3, 7 or U. It is assumed that bridges with an SCR of 0 or 1 are closed and therefore do not need a Post-Flood Inspection.

- Bridges with a substructure unit, abutment, pier, or culvert, protected with scour protection that have a HIGH Hydraulic Vulnerability Classification. Bridges with HIGH Hydraulic Vulnerability Classification shall be added to the Post-Flood Inspection List.

- Bridges which have a Hydraulic Vulnerability Rating of 1 or 2 should be placed on the Post-Flood Inspection List.

- Bridges which have a Hydraulic Vulnerability Rating of 3 or 4 can be placed on the Post-Flood Inspection List at the discretion of the Regional Structures Management Engineer, as recommended by the Regional Hydraulics Engineer. If it is decided to include a bridge on the Post-Flood Inspection List with a Hydraulic Vulnerability Rating of 3 or 4, the rationale used to include it shall be documented in the Hydraulic Vulnerability Assessment for future reference

- Any bridge at regional discretion as determined by the Regional Structures Management Engineer at the discretion of the Regional Hydraulics Engineer.

7.3 Inspection Procedures

Post-Flood inspections should be conducted after every Flood Warning or Flash Flood Warning as issued by the National Weather Service (NWS), New York State Emergency Management Office (SEMO) or after any known instances of localized heavy flooding. Post-Flood Inspections should be completed within two weeks of the flooding event and should not be performed until the flood waters have receded enough to allow the substructure units and the scour protection to be visually inspected. Only bridges in locations covered by the Flood Warning, Flash Flood Warning or actually subjected to flooding need to be inspected. The Regional Hydraulics Engineer should utilize all available resources to determine if a bridge was actually subjected to flood waters. This includes, but not limited to: Flood-Watch Reports, Regional Operations Center (ROC) Reports (if available), River Gage Data and NWS Data. The Regional Structures Management Engineer at the discretion of the Regional Hydraulics Engineer has the authority to decide if a Post-Flood Inspection is not needed.

The Post-Flood inspections should be performed by trained inspection crews designated by the Regional Structures Management Engineer or Regional Bridge Maintenance Engineer

The inspections should consist of a visual inspection of the bridge foundations and scour protection to detect movement, loss of material and other damage related to the flooding. After a Post-Flood Inspection is completed, inspectors shall complete the NYSDOT Post-Flood Inspection Report, found on the Engineering Division-Office of Structures – Structures Management Bureau Webpage at https://www.dot.ny.gov/poa (Form 7.1). In the event a Post-Flood Inspection cannot be completed because of water depths, limited access or any other reason; boat access or a diving inspection should be considered. Regardless, the bridge shall be added to the Flood-Watch List until access is gained and the bridge is determined to be safe. Bridge inspection reports and photographs should be used as a reference to determine the conditions at the bridge before the flood. After the Post-Flood Inspection Report is completed, the report shall be uploaded to the Bridge Data Information System (BDIS) with a copy added to the BIN folder.

7.4 Damage Response Procedures

If the scour protection has been moved or other damage is observed, the inspection crews should consider this a structural flag condition, red or yellow depending on the situation. The flagged conditions shall be documented in a Flagged Bridge Field Report and the Regional Structures Management Engineer shall be immediately notified and informed of the flagged conditions. Detailed bridge flagging procedures are contained in Appendix B of the *New York State Bridge Inspection Manual in effect* (Reference 5).

A repair and maintenance process for scour protection was detailed in a September 20, 1990 memorandum to Regional Directors (Reference 6).

The Regional Structures Management Engineer, upon receipt of the flag notification will notify the Regional Hydraulics Engineer to independently review the site and confirm the findings and the flag status (red vs. yellow vs. no flag necessary). If there are questions about the flag status, the Regional Structures Management Engineer shall have the final determination.

SECTION 8 HYDRAULIC ANALYSIS

8.1 General

The purpose of a detailed **Hydraulic Analysis** is to provide a quantitative assessment of the performance of an existing bridge in comparison to today's hydraulic design requirements.

A hydraulic analysis will define the drainage area and other parameters necessary to determine the discharge rates--and from this, the velocities, the flow depths and the estimated pier and abutment scour depths for the design flood flows. This data will be used to determine the stability of a structure against scour. The analysis results are also necessary to design scour improvements and scour protective countermeasures at a bridge. The data should be used to supplement and refine the information used in the classifying and rating procedures.

It is not intended that every bridge undergo a detailed hydraulic analysis. Generally, a hydraulic analysis is required when:

a) Scour countermeasures are being considered.

b) A Structural Integrity Evaluation (S.I.E.) is being prepared.

c) Whenever it is deemed necessary by the Regional Hydraulics Engineer to better determine Hydraulic Vulnerability.

Detailed instructions on how to perform a hydraulic analysis are beyond the scope of this document and are not included here. The procedures in **Section 3 of the NYSDOT Bridge Manual_US_2019** (Reference 7) provide guidance on how hydraulic studies should be conducted. General procedures which should be followed are outlined in the Section 8.2 of this manual.

8.2 Analysis Procedures

The following procedure is representative of what is required to conduct a Hydraulic Analysis.

a) Determine the design flows from StreamStats, river gage data or any other appropriate method of determining the flow values. For NYS bridges, the Q100 flow will be used in determining the scour depth estimations and the Q500 flow will be used for a check. For interstate bridges the Q500 flow will be used to determine the scour depth estimation.

b) Establish the water surface profiles for the flood flows in Step 1 using the 1D model HEC-RAS or other acceptable modeling application. For the purposes of the vulnerability assessment of existing bridges, the survey requirements for the HEC-RAS analysis can be reduced to four required cross sections. These cross sections should be taken in the following locations.

- 500 feet and 250 feet downstream of the bridge and a bridge length upstream.

- At the upstream face of the bridge.

- Typical approach channel section (approximately one bridge length upstream).

- The upstream face section can be duplicated and adjusted for use as the downstream face cross section.

All the cross sections should be taken perpendicular to the flow for the 100-year flood. Dogleg sections can be used where necessary.

c) Compute the estimated scour depth at the bridge using the procedures in Chapters 4 and 5 of Hydraulic Engineering Circular No. 18 (HEC 18), (Reference 3). The Main Office Hydraulic Unit has prepared a Scour Spreadsheet that uses all the theory contained in the HEC-18 Manual and can be used to calculate the estimated scour depths. Both contraction scour and local scour depths should be evaluated unless the NCHRP abutment scour equation is used, as this method has these scour depths combined within the equations. For pier scour, the *Colorado State University equation* (Eqn. 9, page 52 of HEC 18) is preferred for New York State conditions. For abutments, the conditions at the site will indicate the method to be used. All the pier scour and abutment scour equations are contained in the scour spreadsheet.

d) The results of the analysis should be entered onto a Hydraulic Assessment Summary Sheet (Form 3.1) and kept in the individual BIN folders.

SECTION 9 PROTECTIVE COUNTERMEASURES

9.1 General

The purpose of this section is to identify some of the more common scour protective countermeasures and retrofit actions which are available to make a bridge less vulnerable or invulnerable to damage from scour. This is not a technical design document, as these details are beyond the scope of this discussion. Design requirements and specifications can be found in HEC-18 (Reference 3) and the FHWA publication "HDS 6, *River Engineering for Highway Encroachments*" (Reference 2). This section also includes a discussion on how scour-related improvements should be documented for future reference and inspection purposes.

9.2 Protective Countermeasures

Protective countermeasures are any features installed at a bridge site to reduce the vulnerability of the bridge to damage from scour. These countermeasures are typically used to either protect a bridge from local scour at a pier or abutment or to protect a bridge site through bank protection or stabilization efforts or with stream and channel improvements.

Listed below are examples of some of the methods available to protect a bridge from hydraulic damage. This list is not totally inclusive nor is it intended to limit the types of countermeasures which can be used.

- Placing riprap, stone fill, or sheeting around piers, abutments, or culverts.

- Installing bank protection and stabilization works using riprap, stone fill or stone fill covered with natural vegetation.

- Providing periodic cleaning of aggrading streambeds.

- Installing flow control structures, such as spur dikes, guide banks, rock vanes, rock weirs, rock riffles or check dams.

- Constructing relief bridges or increasing existing bridge openings.

- Gabions, Articulated-Block-Concrete, fully grouted rip rap, or other ridged concrete protections are not recommended as these countermeasures have shown sudden collapse or failure previously in NYS.

There are a wide variety of causes and solutions to scour problems at bridges. Selecting the most appropriate countermeasure should involve a thorough evaluation of the behavior of a stream and the flow patterns through the structure.

HEC-18 (Reference 3) and "HDS 6, River Engineering for Highway Encroachments" (Reference 2) are two sources of information and the bibliography in the "HDS 6, River Engineering for Highway Encroachments" publication contains numerous other references. In addition, the Hydraulic Unit in the Main Office Structures Division is also a valuable resource on this subject.

9.3 Documentation

All scour vulnerability reduction actions should be fully documented for future reference, inspection, and evaluation purposes. This includes all improvements whether the work is accomplished by contract or by state forces. The documentation must be a clear, complete, and accurate representation of the as-built work. It should at the very least include sketches of the improvements showing key dimensions and quantities. If necessary, descriptions of the work should also be included in the documentation package. For more complicated improvements, contract plans should be considered.

Completed documentation packages, including photos should be kept in the BIN folders so they are readily available to bridge inspectors and hydraulic engineers for future reference.

FORMS

It is not required to use provided forms. Forms are included as reference and can be used at the discretion of each evaluating engineer.

Form 3.1 Classifying Summary

Form 3.1 - Classifying Summary

RC:_____ BIN:____________ Name: ______________________ Date:__________

Carried: ____________________ Crossed: ____________________

	SCORE:	Measurements:
General Hydraulic Assessment From Form 3.2		Type of Structure:
Foundation Assessment From Form 3.3.1, 3.3.2, 3.4 (as necessary)		Number of Beams:
		Girder Spacing:
Abutment		Number of Floor beams:
Pier		Piles Present:
Culvert		Clear Span:
		Skew:
Hydraulic Classification Score General + Foundation		Vertical Clearance:
		@
		@
Hydraulic Vulnerability Class		Stream Velocity:
Final Classification Score		@
Low <25 / Medium 25 - 40 / High >35		Scour Along Abutments
		Left:
Comments or Reason for Classification:		Right:
		Scour Along Pier 1:
		Left:
		Right:
		Scour Along Pier 2:
		Left:
		Right:

Recommended Interim Scour Counter Measures:

Additional Comments:

Floodwatch:	
Post Flood:	
FHWA 113:	
Source Code:	

Form 3.2 General Assessment

Form 3.2 - General Asessment

RC: ______ BIN: ____________________ Name: ____ Date: ______________

Carried: ____ Crossed: ____

STREAMBED MATERIAL				
Rock	Boulders	Cobbles	Glacial Till	Alluvium

Scores **Comments**

a. RIVER SLOPE (ft/ft) = S				
Mild	Mild-Med	Med	Med-Steep	Steep
≤0.001	0.0001<S<0.001	0.001<S<0.005	0.005<s<0.02	≥0.02
0	1	2	3	4

Score: 0

b. CHANNEL BOTTOM				
Aggrading	Stable	Degrading	Countermeasure Installed	
			Good	Poor
0	1	2-5	1	3

Score: 0

c. STREAM CONFIGURATION/ALIGNMENT						
Straight	Braided	Stream Alignement (Degrees)			Countermeasures Installed	
0-15 Degrees		15-30	30-45	>4	Good	Poor
0	1	2	3		1	3

Score: 0

d. DEBRIS / ICE PROBLEMS					
No Effect	Minor Effect		Major Effect		
0	1	2	3	4	5

Score: 0

e. NEAR RIVER CONFLUENCE	
No	Yes
1	2

Score: 0

f. AFFECTED BY BACKWATER	
No	Yes
1	0

Score: 0

g. EXISTING / HISTORIC SCOUR DEPTHS			
None	Small	Medium	Large
	<1'	1'-3'	>3'
0	1	2-3	4-5

Score: 0

h. MAXIMUM FLOOD DEPTHS		
Small (<5')	Medium (5'-10')	Large (>10')
1	2	3

Score: 0

i. WATERWAY OPENING		
Good	Fair	Poor
0	3	5

Score: 0

i. OVERFLOW / RELIEF AVAILABLE	
No	Yes
1	2

Score: 0

Total: 0

Form 3.3.1 Foundation Assessment – Abutment

Form 3.3.1 Foundation Asessment - Abutment

RC:______ BIN:________________________ Name: ________________________________ Date: ____________

Carried: ____ Crossed: ____

Scores

Left Right

a. EXISTING SCOUR PROTECTION							
Not Required	Sheet Pile Wall	Cofferdam	Rip-Rap			Other	None
			Good	Fair	Poor		
0	0-3	0	2	3	4	3	5

Left ________ Right ________

Notes:

b. ABUTMENT FOUNDATION									
A	B	C	D	E	F	G	H	I	J
Spill-Through				Vertical Wall					
Long Piles >20 ft Non-Erodible Rock	Short Piles <20 ft Timber Piles Erodible Rock	Spread On Earth	UNKNOWN	Long Piles >20 ft Non-Erodible Rock	Long Timber Piles >20 ft	Short Piles <20 ft Erodible Rock	Sheet Pile Wall with Unknown Length	Spread On Earth	UNKNOWN
0	2	3	3	0	3	5	7	10	10

Notes:

Left ________ Right ________

c. ABUTMENT LOCATION ON RIVER BEND		
Inside	Straight	Outside
0	0	2

Left ________ Right ________

Notes:

d. ANGLE OF INCLINATION (180° - A°)			
0° - 20°	20° - 45°	45° - 90°	>90°
0	1	2	4

Left ________ Right ________

Notes:

e. EMBANKMENT ENCROACHMENT		
Approximate Conveyance Restricted (%)		
<10%	10% - 25%	>25%
Small	Medium	Large
0	2	4

Left ________ Right ________

Notes:

Total _______

Critical Abutment Score _______

Additional Comments, Sketches, Notes (Use back if necessary):

Form 3.3.2 Foundation Assessment – Pier(s)

Form 3.3.2 Foundation Assessment - Pier(s)

RC: ______ BIN: ______________________ Name: ______________________________ Date: ______________

Carried: ______________________________________ Crossed: ______________________________________

Scores

Pier #1 ________ Pier #2 ________ Pier #3 ________ Pier #4 ________

a. EXISTING SCOUR PROTECTION							
Not Required	Sheet Pile Wall	Cofferdam	Rip-Rap			Other	None
			Good	Fair	Poor		
0	0-3	0	2	3	4	3	5

Notes:

b. PIER FOUNDATION						
A	B	C	D	E	F	G
Steel Piles Concrete Piles* ≥20 ft with Reinforcement Below Calculated Scour Depth *Can use if <20 and Designed to Resist Scour	Spread On Non-Erodible Rock	Concrete Piles ≤20 ft with Reinforcement Above Calculated Scour Depth or Unknown Reinforcement Depth Below Streambed	Timber Piles	Spread on Erodible Rock	Spread On Earth	U N K N O W N
0	0	3	4	5	10	10

Notes:

________ ________ ________ ________

c. FOOTING / PILE BOTTOM BELOW STREAM BED					
>20 ft	15-20 ft	10-15 ft	7-10 ft	4-7 ft	<4 ft
0	1	2	3	4	5

Notes:

________ ________ ________ ________

d. PIER ANGLE OF ATTACK (DEGREES)			
0° OR CYLINDRICAL	0° - 20°	20° - 45°	45° - 90°
0	2	3	4

Notes:

________ ________ ________ ________

e. PIER WIDTH (ft)				
<3 ft	3-5 ft	5-8 ft	8-10 ft	>10 ft
1	2	3	4	5

Notes:

________ ________ ________ ________

f. SIMPLE SPANS	
No	Yes
0	1

Notes:

________ ________ ________ ________

Total ________

Critical Pier Score ________

Form 3.4 Foundation Assessment – Culvert

Form 3.4 - Foundation Assessment - Culvert

RC: ______ BIN: ________________ Name: ________________________________ Date: ______________

Carried: ____ Crossed: ____

Scores

EXISTING SCOUR COUNTERMEASURES AT CLOSED CONDUIT CULVERT OUTLET								
Not Required	Cutoff Wall (≥3.5 ft)			Riprap			Other	None
	<20% Exposed	20%-50% Exposed	>50% or Undermined	Good	Fair	Poor		
0	0	3	5	1	3	4	1-2	5

Score: ________

Comments:

CULVERT FOUNDATION									
A	B	C	D	E	F	G	H	I	J
RIGID FRAMES					FLEXIBLE STRUCTURES				
3 - Sided on Long Piles or Non-Erodible Rock	3 - Sided on Short Piles or Erodible Rock	3 - Sided on Spread Footing on Erodible Soil or Unknown Foundation	Large Four-Sided Structure >20 feet	Multiple Small Box Structure Each ≤ 10 feet	3 - Sided Arch on Long Piles or Non-Erodible Rock	3 - Sided Arch on Short Piles or Erodible Rock	3 - Sided on Spread Footing on Erodible Soil or Unknown Foundation	Large Metal Box Structure or Pipe >20 feet	Multiple Small Metal Box or Pipe Each ≤ 10 feet
0	2	3	0	4	4	5	7	6	8

Score: ________

Comments:

PRIMARY ELEMENT CONDITION STATE				
100% CS 1	90% CS 3	<20% CS 4	20% - 50% CS 4	>50% CS 4
0	1	3	4	5

Score: ________

Comments:

ANGLE OF ATTACK (DEGREES)			
0	0° - 20°	20° - 45°	45° - 90°
0	1	3	4-5

Score: ________

Comment:

TRAPPED DEBRIS/SEDIMENT		
Small	Medium	Large
0	1	3

Score: ________

Comments:

Total: 0

Form 4.1 Vulnerability Rating Summary

Form 4.1 - Vulnerability Rating Summary

RC: ______ BIN: ____________________ Name: ____ Date: _____________

Carried: ____ Crossed: ____

LIKELIHOOD SCORE			
VULNERABILITY CLASSIFICATION			
HIGH	MEDIUM	LOW	NOT VULNERABLE
10	6	2	0

Score **Comments**

CONSEQUENCE SCORE		
FAILURE TYPE		
CATASTRPHIC	PARTIAL COLLAPSE	STRUCTURAL DAMAGE
5	3	1

EXPOSURE SCORE		
TRAFFIC VOLUME (AADT)		
<2,5000	4,000 - 25,000	<4,000
2	1	0

EXPOSURE SCORE			
FUNCTIONAL CLASSIFICATION			
INTERSTATE & FREEWAY	ARTERIAL	COLLECTOR	LOCAL ROAD & BELOW
3	2	1	0

Total __________

Vulnerability Rating Score (Number) __________

Additional Notes/Comments:

Vulnerability Rating Scores:

Rating	Number	Description
>15	1	Safety Priority
13-16	2	Safety Program
9-14	3	Capital Program
<15	4	Inspection Program
<9	5	No Action
—	6	Not Applicable

Form 6.1 Flood-Watch Logs

Bridge Flood Warning Report

Date:		Name:		Name:	

Bin:		County:	
Carried:		Risk Category:	
Crossed:		Ref Marker:	
Span Type:		No. of Spans:	
Critical Condition:			

Inspection Log:

	Bridge Critical Items:					Highway			Stream					
Military Time:	Alignment:	Profile:	Vibration:	Noise:	Estimated Freeboard:	Erosion:	Settlement:	Cracking:	Debris Flow:	Impacting Debris:	Snagging Debris:	Change of Flow Characteristics:	Erosion:	Noise:
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	Y N	E M G	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N	Y N

Remarks: ____

BRIDGE FLOOD-WATCH
GENERAL INSTRUCTIONS

Visually inspect bridge, stream and approach roadway each time the bridge is visited if on a roving patrol or about every half-hour if stationed at the bridge. When the water is above the critical freeboard elevation, a stationary watch at the bridge must be established. For those items inspected, circle the appropriate response. If not inspected, leave blank. Circle N for no, none or no change in condition since beginning of flood watch. Circle Y for yes if a change has occurred. A "yes" response requires a written explanation of what was observed or changed. Record under freeboard the Estimated, Measured, Gage readings and circle E, M, or G as appropriate. Inspections should include but not be limited to the upstream and downstream sides of the bridge, the upstream and downstream sides of the channel near the bridge and the approach roadways to the bridge. A "yes" response for Critical items requires the bridge to be closed unless there are valid reasons known that the bridge remains safe. Should you believe that the bridge is becoming unsafe for any reason, immediately close the bridge and then notify the Resident Engineer and your supervisor. The bridge will only be reopened with the approval of a licensed engineer.

LINE ITEM DESCRIPTION:

TIME – Military Time

BRIDGE

a. Alignment- Sight along fascia, railing, curb, paint stripping, etc... for horizontal discontinuity or misalignment. Record the amount of misalignment between spans.

b. Profile- Sight along fascia, railing, curb, paint striping, etc... for vertical discontinuity or misalignment. Record the amount of misalignment between spans.

c. Length- Inspect joints in deck, railing, curbs and sidewalks at the abutments and piers for widening or closing. Record the distance that the joint has opened or closed.

d. Tilt- Check the abutments and piers for plumbness and check the bearings for a change in inclination.

e. Vibration- When there is no traffic on the bridge, check each span for vibration or swaying motion due to stream flow.

f. Noise- When there is no traffic on the bridge, listen for creaks, groans, snapping, cracking, scraping or popping noises coming from the bridge.

g. Freeboard- Measure the distance from the lowest point on the bottom of the bridge superstructure to the water surface to the nearest half foot. If the water level is above the bottom of the superstructure, the bridge should be closed immediately.

HIGHWAY

a. Erosion- Check approach roadways, embankment slopes, shoulders, and pavement for erosion. Extend limits of inspection to cover roadways parallel to stream

b. Settlement- Check items listed under Erosion for settlement.

c. Cracking- Note any new cracks in pavement or deck

STREAM

a. Debris Flow- Record the quantity of ice, brush, trees, logs, etc... carried in the stream as "N" for none, "L" for light, "M" for medium, and "H" for heavy

b. Impacting Debris- Is any debris or ice hitting the superstructure?

c. Snagging Debris- Is any debris or ice caught or snagged on the superstructure, substructures or along the stream channel? Note in the Remarks section where the debris is snagging.

d. Flow Characteristics- Have the flow characteristics of the stream changed? (i.e. location of eddys, strength and direction of currents, location of standing waves, location of boils, etc...)

e. Erosion- Is there any observed erosion occurring along stream banks, stream bottoms, or around bridge substructures.

f. Noise- Can you hear stones or other objects rolling or sliding along the stream bed?

Bridge Size Metal Culvert Flood Warning Report

Date:		Name:		Name:	
Bin:			County:		
Carried:			Risk Category:		
Crossed:			Ref Marker:		
Span Type:			No. of Spans:		
Critical Condition:					

Inspection Log:

	Bridge Size Metal Culvert							Highway			Stream				
	Non-Critical:				Critical Items:						Non- Critical				
Military Time:	Submerged Inlet:	Noise:	Erosion:	Estimated Freeboard:	Plugged:	Deformation:	Piping:	Overtopping:	Settlement:	Cracking:	Debris Flow:	Impacting Debris:	Snagging Debris:	Change of Flow Characteristics:	Erosion:
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N
	Y N	Y N	Y N	E M G	Y N	Y N	Y N	Y N	Y N	Y N	N L M H	Y N	Y N	Y N	Y N

Remarks: ____

____

____

____

____

____

____

____

CULVERT FLOOD WATCH
GENERAL INSTRUCTIONS

Visually inspect bridge, stream and approach roadway each time the bridge is visited if on a roving patrol or about every half-hour if stationed at the bridge. When the water is above the critical freeboard elevation, a stationary watch at the bridge must be established. For those items inspected, circle the appropriate response. If not inspected, leave blank. Circle N for no, none or no change in condition since beginning of flood watch. Circle Y for yes if a change has occurred. A "yes" response requires a written explanation of what was observed or changed. Record under freeboard the Estimated, Measured, Gage readings and circle E, M, or G as appropriate. Inspections should include but not be limited to the upstream and downstream sides of the bridge, the upstream and downstream sides of the channel near the bridge and the approach roadways to the bridge. A "yes" response for Critical items requires the bridge to be closed unless there are valid reasons known that the bridge remains safe. Should you believe that the bridge is becoming unsafe for any reason, immediately close the bridge and then notify the Resident Engineer and your supervisor. The bridge will only be reopened with the approval of a licensed engineer.

LINE ITEM DESCRIPTION:

TIME – Military Time

BRIDGE

a. Submerged Inlet - Note if the culvert opening has become submerged. Some structures are designed for pressure flow conditions. However, this may indicate the structure is partially plugged with debris or sediment. Monitor the structure continuously if the inlet is submerged and water level rises to within three feet of the raodway surface. Close the structure immediately if the roadway is overtopped.

b. Noise - Can you hear large stones or other objects rolling or sliding along the stream bed or culvert? If "yes", begin monitoring the structure continuously. Close the structure immediately if there are any signs of deformation or settlement.

c. Erosion - Is there any observed erosion occuring around culvert openings, headwalls or wingwalls? If "yes" begine monitoring the structure continuously. Close the structure imeediately if there are any signs of deformation or settlement.

d. Freeboard - Measure the distance from the highest point to the underside of the culvert pipe to the water surface to the nearest half foot. If safety concerns prohibit taking measurements, estimate the remaining freeboard.

e. Plugged - Does the structure appear to be completely plugged with debris or sediment? If "yes" close the structure imeediately.

f. Deformation - Is the geometry of the structure changing? Obvious signs of deformation indicate a serious structural failure. If "yes" close the structure immediately.

g. Piping - Is water flowing along the outside of the pipe, under the roadway, through the embankment material? If "yes" close the structure immediately.

HIGHWAY

a. Overtopping - Is the raodway in danger of being topped? If "yes" close the structure immediately.

b. Settlement- Is the raodway or embankment settling in the vicinity of the culvert? If "yes" close the structure immediately.

c. Cracking- Are new cracks forming in the roadway or embankments above the culvert? If "yes" close the structure immediately.

STREAM

a. Debris Flow- Record the quantity of ice, brush, trees, logs, etc... carried in the stream as "N" for none, "L" for light, "M" for medium, and "H" for heavy

b. Impacting Debris- Is any debris or ice hitting the structure? Monitor continuously if there is medium to heavy debris flow. Close the structure immediately if it becomes plugged with debris.

c. Snagging Debris- Is any debris or ice caught or snagged on the superstructure, substructures or along the stream channel? Note in the Remarks section where the debris is snagging.

d. Flow Characteristics- Have the flow characteristics of the stream changed? (i.e. location of eddys, strength and direction of currents, location of standing waves, location of boils, etc...) Is the stream attacking the embankments?

e. Erosion- Is there any observed erosion occurring along stream banks, stream bottoms, or around bridge

Form 7.1 Post-Flood Inspection

NYSDOT POST FLOOD INSPECTION REPORT

BIN: ______________________ DATE: ______________________
COUNTY: ______________________ TIME: ______________________
OVER: ______________________ INSPECTOR: ______________________
UNDER: ______________________ SIGNATURE: ______________________

PICTURES? YES NO

SUPERSTRUCTURE:	YES	NO
Bridge rail Alignment normal	___	___
Curb alignment normal	___	___
Joint seals normal & show no distress	___	___
Deck & approach pavements show no new cracks	___	___

Comments:

____

____

SUBSTRUCTURE:	YES	NO
Footings exposed	___	___
Scour holes present (depth?)	___	___
Stone fill/ scour protection stable	___	___

Comments:

____

____

WATERWAY:

Adequate opening	YES NO MAYBE
Debris in opening	HEAVY MODERATE LIGHT NONE
High water mark – as freeboard =	______________________
Siltation in opening	HEAVY MODERATE LIGHT NONE
Bank cutting	UPSTREAM DOWNSTREAM SEVERE MODERATE MINOR
Alignment with structure	GOOD FAIR POOR
Ice Jam near structure	MAJOR MINOR NONE
Piers – Debris	MAJOR MINOR NONE

Comments:

____

____

Dropline/Scour Documentation attached: YES NO
(Required ONLY if a visual inspection is not possible)

Diving Required? YES NO (if so, where?)

____

____

Follow-up inspection by Hydraulics Unit? YES NO
Describe Condition:

____

____

Follow-up repairs recommended? YES NO
Describe recommended repairs:

____

____

Bridge flagged? RED YELLOW SAFETY NONE
Describe flagged condition:

____

____

RESOURCES

1. Bridge Safety Assurance Task Force Report

2. River Engineering for Highway Encroachments - HDS 6

3. Chapters 4 & 5 of Hydraulic Engineering Circular No. 18 (HEC 18)

4. New York State Department of Transportation Bridge Inventory Manual", New York State Department of Transportation, Albany, NY July 2020.

5. New York State Bridge Inspection Manual 2017 – Appendix B *Inspection Flagging Procedure*

6. Memorandum: M. J. Cuddy, Office of Engineering & D. N. Geoffroy, Office of Operations to Regional Directors, R1-11, Subject: Monitoring and Maintenance of Scour Protection, September 20, 1990, New York State Department of Transportation, Albany, NY. (Update)

7. New York State Department of Transportation Bridge Manual_US_2019, Albany, NY (2019).

APPENDIX A HYDRAULIC VULNERABILITY RATING DEFINITIONS

VULNERABILITY RATING SCALE

1. SAFETY PROGRAM WATCH – This rating designates a vulnerability to failure resulting from loads or events that may occur in the next few years. Corrective or mitigating action, enhanced inspection or other appropriate safety action, such as placing on a flood watch, shall be taken. If corrective or mitigating action is not immediately taken, placing the bridge on the current Five-Year Capital Program along with appropriate interim safety action, such as continued monitoring or traffic restrictions, shall be considered.

2. SAFETY PROGRAM ALERT – This rating designates a vulnerability to failure resulting from loads or events that may occur but are not likely in the next few years. Remedial work to reduce the vulnerability or enhanced monitoring is not an immediate priority but may be needed in the near future. Placing the bridge on the Capital Program should be considered.

3. CAPITAL PROGRAM ACTION – This rating designates a vulnerability to failure resulting from extreme loads or events that are possible but not likely. This risk can be tolerated until a normal capital construction project can be implemented.

4. INSPECTION PROGRAM ACTION – This rating designates a vulnerability to failure presenting minimal risk providing that anticipated conditions or loads on the structure do not change. Unexpected failure can be avoided during the remaining life of the structure by performing the normal scheduled bridge inspections with attention to factors influencing the vulnerability of the structure.

5. NO ACTION – This rating designates a vulnerability to failure which is less than or equal to the vulnerability of a structure built to the current design standards. Likelihood of failure is remote.

6. NOT APPLICABLE – This rating designates there is no exposure to a specific type of vulnerability.

APPENDIX B – NBI 113 CODE/NYSDOT ADDITIONAL GUIDANCE

INTRODUCTION

The purpose of this Appendix is to provide Regional and Consultant Hydraulic Engineers guidance on assigning an NBI Item 113 Scour Critical Rating (SCR) Code for foundations on bridge sized structures (span > 20 feet) which cross water. The guidance contained within supersedes all previous New York State Department of Transportation memos/TAs/guidance regarding assignment of the NBI Item 113 Scour Critical Codes.

IMPLEMENTATION

This guidance shall be used by State and Consultants Hydraulic Engineers responsible for (re)assessing the NBI Item 113 SCR Code for NYSDOT and locally owned bridge structures.

The NBI Item 113 SCR Code should be (re)assessed when:

- A new structure over water is built
- An existing structure over water receives channel rehabilitation/improvements
- A bridge inspection Team Leader submits a Hydraulic Vulnerability Assessment request form

The NYSDOT Hydraulic Vulnerability Classification Score and Class, Foundation Type and recent scour conditions observed at the field, shall be used to assign the NBI 113 SCR Code to the structure.

- The Hydraulic Vulnerability Classification Score and Class for a bridge may be found in the NYSDOT Bridge Data Information System (BDIS) Active Hydraulics Vulnerabilities tab (BDIS path: Structure Manager > Bridges & Culverts > Vulnerability > Hydraulic > Hydraulic – Active).
- If unknown, the Foundation Type should be determined by obtaining record plans, review of the BIN folder, inspection reports and BDIS Active Inventory, and/or site visit.
- The physical scour condition observed at the foundation should be obtained by referring to a bridge inspection report and/or by site visit.

The Hydraulic Engineer shall use the above information in conjunction with either the Bridge Structures or Culvert Structures (Bridge Size) tables presented below, as deemed appropriate for the structure configuration.

If conditions arise that are not outlined in the following tables, then the Hydraulic Engineer shall assign an NBI Item 113 Code, based on judgement, with documentation supporting their choice.

Changes in the NBI Item 113 Code that results in a structure being classified as Scour Critical (Item 113 = 0, 1, 2, 3, 7, and U) shall be communicated to the Bridge Owner to develop a Plan of Action (POA) for that structure.

FHWA NBI ITEM 113 SCOUR CRITICAL CODES (use for reference with tables below)

CODE		DESCRIPTION (See the Federal Coding Guide for the full description of the codes.)
N		Bridge not over Waterway
U		Bridge is on Unknown Foundation
T		Bridge over tidal waters that has not been evaluated for scour but considered low risk.
9		Bridge foundations (including Piers/piles) are on dry land well above flood levels
8		Bridge foundations determined to be stable for the assessed scour condition. Scour is determined to be above top of footing.
7		Countermeasures have been installed to mitigate an existing problem with scour and to reduce the risk of bridge failure during a flood event. Instructions contained in a plan of action have been implemented to reduce the risk to users from a bridge failure during or immediately after a flood event.
6		Scour calculation/evaluation has not been made.
5	**5D**	Bridge foundations determined to be stable for assessed or calculated scour condition. The substructure unit was **D**esigned to be stable after a design scour event (example a 100-year storm event). The foundation was designed to be below or within the calculated scour depth, or the foundations are supported on long piles that will be stable below the assessed or calculated scour depth.
	5S	The bridge foundation was found to be unstable for assessed or calculated scour conditions. However, by the addition of a well-designed **S**cour countermeasure and/or **S**cour protection (see HEC 23), the foundations are assessed to be stable. The safety of the bridge during a storm event will depend on the condition of the installed scour countermeasure/protection during the life of the bridge.
	5R	Bridge foundations determined to be stable for assessed or calculated scour condition. Bridge foundations are on **R**ock formations that have been determined to resist scour within the service life of the bridge.
4		Bridge foundations determined to be stable for assessed or calculated scour conditions; field review indicates action is required to protect exposed foundations
3		Bridge is scour critical; bridge foundations determined to be unstable for assessed or calculated scour conditions. No scour observed at the bridge foundation.
2		Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations.
1		Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic. Failure is imminent.
0		Bridge is scour critical. Bridge has failed and is closed to traffic

BRIDGE STRUCTURES

<table>
<tr><th colspan="2">HVA CLASSIFICATION</th><th rowspan="2">FOOTING TYPE (BRIDGES)</th><th colspan="3" rowspan="2">SCOUR CONDITION AT FOOTINGS</th><th rowspan="2">ITEM 113 SCOUR CRITICAL CODE</th></tr>
<tr><th>SCORE</th><th>CLASS</th></tr>
<tr><td rowspan="6">>35</td><td rowspan="6">HIGH</td><td rowspan="6">Spread on Earth/ Erodible Rock/Short Piles (< 20’)</td><td colspan="3">No Scour Protection</td><td>3</td></tr>
<tr><td colspan="3">Scour Protection Installed Randomly</td><td>7</td></tr>
<tr><td colspan="3">Well Designed Scour Protection Installed Properly</td><td>5S</td></tr>
<tr><td rowspan="3">Footings Undermined</td><td colspan="2">Bridge Open</td><td>2</td></tr>
<tr><td colspan="2">Bridge Closed</td><td>1</td></tr>
<tr><td colspan="2">Bridge Failed</td><td>0</td></tr>
<tr><td rowspan="22">20 - 40</td><td rowspan="22">MEDIUM</td><td rowspan="15">Spread on Earth</td><td rowspan="6">No Historic/ Documented Scour Problem</td><td rowspan="2">No Scour Protection</td><td>Footing Covered</td><td>8</td></tr>
<tr><td>Footing Exposed</td><td>5D</td></tr>
<tr><td rowspan="2">Random Scour Protection Installed</td><td>Footing Covered</td><td>8 or 5S</td></tr>
<tr><td>Footing Exposed</td><td>5S</td></tr>
<tr><td rowspan="2">Well Designed Scour Protection Installed</td><td>Footing Covered</td><td>8 or 5S</td></tr>
<tr><td>Footing Exposed</td><td>5S</td></tr>
<tr><td rowspan="6">Historic/ Documented Scour Problem Exist</td><td rowspan="2">No Scour Protection</td><td>Footing Covered</td><td>3</td></tr>
<tr><td>Footing Exposed</td><td>3</td></tr>
<tr><td rowspan="2">Random Scour Protection Designed Installed</td><td>Footing Covered</td><td>7</td></tr>
<tr><td>Footing Exposed</td><td>7</td></tr>
<tr><td rowspan="2">Well Designed Scour Protection Installed</td><td>Footing Covered</td><td>8 or 5S</td></tr>
<tr><td>Footing Exposed</td><td>5S</td></tr>
<tr><td rowspan="3">Footings Undermined</td><td colspan="2">Bridge Open</td><td>2</td></tr>
<tr><td colspan="2">Bridge Closed</td><td>1</td></tr>
<tr><td colspan="2">Bridge Failed</td><td>0</td></tr>
<tr><td rowspan="7">Erodible Rock/Short Piles (< 20’)</td><td rowspan="3">No Scour Protection or Installed Randomly</td><td rowspan="2">Rock or Piles</td><td>Footing Covered</td><td>8 or 5R</td></tr>
<tr><td>Footing Exposed</td><td>5R or 4</td></tr>
<tr><td colspan="2">Rock or Piles Exposed</td><td>4 or 3</td></tr>
<tr><td colspan="2" rowspan="2">Well Designed Scour Protection Installed</td><td>Footing Covered</td><td>8 or 5S</td></tr>
<tr><td>Footing Exposed</td><td>5S</td></tr>
<tr><td rowspan="2">Footings Undermined</td><td colspan="2">Bridge Open</td><td>4, 3, or 2</td></tr>
<tr><td colspan="2">Bridge Closed</td><td>1</td></tr>
</table>

HVA CLASSIFICATION		FOOTING TYPE (BRIDGES)	SCOUR CONDITION AT FOOTINGS			ITEM 113 SCOUR CRITICAL CODE
SCORE	**CLASS**					
20 - 40	**MEDIUM**	Long Piles/ Non-Erodible Rock	No Scour Protection		Footing Covered	8 or 5D,5R
					Footing Exposed	5D, 5R
			Scour Protection Installed Randomly		Footing Covered	8 or 5S, 5R
					Footing Exposed	5S, 5R
			Well Designed Scour Protection Installed		Footing Covered	8 or 5D, 5S, 5R
					Footing Exposed	5D, 5S, 5R
			Footings Undermined	Bridge Open		4
				Bridge Closed		1
				Bridge Failed		0
< 25	**LOW**	Spread on Earth	No Historic/ Documented Scour Problem	No Scour Protection	Footing Covered	8
					Footing Exposed	5D
				Random Scour Protection Installed	Footing Covered	8 or 5D
					Footing Exposed	5D
				Well Designed Scour Protection Installed	Footing Covered	8 or 5D, 5S
					Footing Exposed	5D, 5S
			Footings Undermined	Bridge Open		2
				Bridge Closed		1
				Bridge Failed		0
		Erodible Rock/Short Piles (< 20')	No Scour Protection or Installed Randomly	Rock or Piles	Footing Covered	8 or 5D, 5R
					Footing Exposed	5D, 5R or 4
				Rock or Piles Exposed		4
			Well Designed Scour Protection Installed		Footing Covered	8 or 5D,
					Footing Exposed	5D
			Footings Undermined	Bridge Open		4, 3, or 2
				Bridge Closed		1
				Bridge Failed		0
		Long Piles/ Non-Erodible Rock	No Scour Protection		Footing Covered	8 or 5D
					Footing Exposed	5D
			Scour Protection Installed Randomly		Footing Covered	8 or 5D
					Footing Exposed	5D
			Well Designed Scour Protection Installed		Footing Covered	8 or 5D, 5S
					Footing Exposed	5D
			Footings Undermined	Bridge Open		4
				Bridge Closed		1
				Bridge Failed		0

CULVERT STRUCTURES (BRIDGE SIZE)

CULVERT TYPE	HVA CLASSIFICATION SCORE	HVA CLASSIFICATION CLASS	SCOUR/CONDITION STATE (CS) OBSERVATION AT CULVERT		ITEM 113 SCOUR CRITICAL CODE
THREE SIDED STRUCTURES WITH FOOTINGS *(Arches, Frames)*	**>35**	**HIGH**	Follow observation outlined under Bridge Structures		Follow Bridge Guidance
	20 - 40	**MEDIUM**	Follow observation outlined under Bridge Structures		Follow Bridge Guidance
	< 25	**LOW**	Follow observation outlined under Bridge Structures		Follow Bridge Guidance
FOUR-SIDED CONCRETE STRUCTURES, THREE-SIDED CONCRETE STRUCTURES WITH BOTTOM SLAB, WITH/WITHOUT A CUTOFF WALL	**>35**	**HIGH**	Cutoff wall not exposed		3, 5D, 5S, 7 or 8
			Cutoff wall exposed but not undermined		2 or 3
			Cutoff Wall Undermined	Structure Open	2
				Structure Closed	1
				Structure Failed	0
	20 - 40	**MEDIUM**	Cutoff wall not exposed		5D, 5S, 7 or 8
			Cutoff wall exposed but not undermined		2, 4, 5D, 5S, 7
			Cutoff Wall Undermined	Structure Open	2, 4
				Structure Closed	1
				Structure Failed	0
	< 25	**LOW**	Cutoff wall not exposed		8
			Cutoff wall exposed but not undermined		5D, 5S
			Cutoff Wall Undermined	Structure Open	3 or 4
				Structure Closed	1
				Structure Failed	0

<u>**CULVERT STRUCTURES (BRIDGE SIZE)**</u>

<table>
<tr><th rowspan="2">CULVERT TYPE</th><th colspan="2">HVA CLASSIFICATION</th><th rowspan="2" colspan="2">SCOUR/CONDITION STATE (CS) OBSERVATION AT CULVERT</th><th rowspan="2">ITEM 113 SCOUR CRITICAL CODE</th></tr>
<tr><th>SCORE</th><th>CLASS</th></tr>
<tr><td rowspan="18">CLOSED METAL STRUCTURES

ROUND PIPES/PIPE ARCHES/BOXES WITH/WITHOUT A CUTOFF WALL</td><td rowspan="6">>35</td><td rowspan="6">HIGH</td><td colspan="2">Cutoff wall not exposed, Primary Element CS ≤ 2</td><td>5D, 5S, 7 or 8</td></tr>
<tr><td colspan="2">Cutoff wall not exposed, Primary Element CS ≥ 3</td><td>2, 3 or 7</td></tr>
<tr><td colspan="2">Cutoff wall exposed but not undermined, Primary Element CS ≥ 3</td><td>2 or 3</td></tr>
<tr><td rowspan="3">Cutoff Wall Undermined, Primary Element CS ≥ 3</td><td>Structure Open</td><td>2</td></tr>
<tr><td>Structure Closed</td><td>1</td></tr>
<tr><td>Structure Failed</td><td>0</td></tr>
<tr><td rowspan="6">20 - 40</td><td rowspan="6">MEDIUM</td><td colspan="2">Cutoff wall not exposed, Primary Element CS ≤ 2</td><td>5D, 5S, 7 or 8</td></tr>
<tr><td colspan="2">Cutoff wall not exposed, Primary Element CS ≥ 3</td><td>2, 3, 5D, 5S, 7</td></tr>
<tr><td colspan="2">Cutoff wall exposed but not undermined, Primary Element CS ≥ 3</td><td>2, 3, 4, 7</td></tr>
<tr><td rowspan="3">Cutoff Wall Undermined, Primary Element CS ≥ 3</td><td>Structure Open</td><td>2, 4</td></tr>
<tr><td>Structure Closed</td><td>1</td></tr>
<tr><td>Structure Failed</td><td>0</td></tr>
<tr><td rowspan="6">< 25</td><td rowspan="6">LOW</td><td colspan="2">Cutoff wall not exposed, Primary Element CS ≤ 2</td><td>8</td></tr>
<tr><td colspan="2">Cutoff wall not exposed, Primary Element CS ≥ 3</td><td>3</td></tr>
<tr><td colspan="2">Cutoff wall exposed but not undermined, Primary Element CS ≥ 3</td><td>2, 3</td></tr>
<tr><td rowspan="3">Cutoff Wall Undermined, OR Primary Element CS ≥ 3</td><td>Structure Open</td><td>3 or 4</td></tr>
<tr><td>Structure Closed</td><td>1</td></tr>
<tr><td>Structure Failed</td><td>0</td></tr>
</table>

REFERENCES

NYSDOT Hydraulic Vulnerability Manual, Revised 2022

FHWA Technical Advisory (TA) T5140.23, Evaluating Scour at Bridges, October 28, 1991

FHWA HEC 18, Evaluating Scour at Bridges, Fifth Edition, April 2012

FHWA HEC 23, Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance, Third Edition, September 2009

FHWA's Memorandum on "Compliance with the National Bridge Inspection Standards; Plan of Action for Scour Critical Bridges" by King W. Gee, dated July 24, 2003.

FHWA's Memorandum on "Revision of Coding Guide, Item 113 - Scour Critical Bridges" by James D. Cooper, Director of Bridge Technology, dated April 27, 2001.

DOCUMENTATION

Changes to FHWA NBI 113 Scour Critical Codes should be documented in BDIS under the Hydraulic Vulnerability Assessment Tab.

CONTACT

Questions concerning NBI 113 Code or NYSDOT Additional Guidance should be addressed to the Structure Management Bureau in the Office of Structures.

APPENDIX C T5140.23 EVALUATING SCOUR AT BRIDGES

FHWA Technical Advisory - Evaluating Scour at Bridges

October 28, 1991

T5140.23

PURPOSE To provide guidance on developing and implementing a scour evaluation program for:

1. designing new bridges to resist damage resulting from scour
2. evaluating existing bridges for vulnerability to scour
3. using scour countermeasures; and
4. improving the state-of-practice of estimating scour at bridges.

CANCELLATION Technical Advisory T 5140.20, Scour at Bridges, dated September 16, 1988, is cancelled.

BACKGROUND

1. The need to minimize future flood damage to the Nation's bridges requires that additional attention be devoted to developing and implementing improved procedures for designing, protecting and inspecting bridges for scour. (See National Bridge Inspection Standards, 23 CFR 650 Subpart C.) Current information on this subject has been assembled in the Federal Highway Administration (FHWA) design publication Hydraulic Engineering Circular (HEC) 18, "Evaluating Scour at Bridges," FHWA-IP-90-017.
2. Paragraph 4 contains the FHWA recommendations for developing and implementing a scour evaluation program. The recommendations have been developed based on the review and evaluation of the existing policies and guidance pertaining to bridge scour set forth in paragraph 5. The procedures in HEC 18 provide approaches for implementing these recommendations.

RECOMMENDATIONS FOR DEVELOPING AND IMPLEMENTING A SCOUR EVALUATION PROGRAM. Every bridge over a waterway, whether existing or under design, should be evaluated as to its vulnerability to scour in order to determine the prudent measures to be taken for its protection. Most waterways can be expected to experience scour over a bridge's service life (which could approach 100 years). Exceptions might include waterways in massive, competent rock formations where scour and erosion occur on a scale that is measured in centuries. (See HEC 18, Chapter 2.) The added cost of making a bridge less vulnerable to scour is small when compared to the total cost of a failure which can easily be two or three times the original cost of the bridge. Moreover, the need to ensure public safety and to minimize the adverse effects stemming from bridge closures requires the best effort to improve the state-of-practice of designing and maintaining bridge foundations to resist the effects of scour. The recommendations listed below summarize the essential elements which should be addressed in developing a program for evaluating bridges and providing countermeasures for scour. Detailed guidance regarding approaches for implementing the recommendations is included in HEC 18.

1. Interdisciplinary Team. Scour evaluations of new and existing bridges should be conducted by an interdisciplinary team comprised of hydraulic, geotechnical, and structural engineers. (See HEC 18, Chapters 3 and 5.)
2. New Bridges. Bridges over tidal and non-tidal waterways with scourable beds should withstand the effects of scour from a superflood (a flood exceeding the 100-year flood) without failing, i.e., experiencing foundation movement of a magnitude that requires corrective action.
    - (1) Hydraulic studies should be prepared for bridges over waterways in accordance with Article 1.3.2 of the Standard Specifications for Highway Bridges of the American Association of State Highway and Transportation Officials (AASHTO) and the floodplain regulation of the FHWA as set forth in 23 CFR 650, Subpart A.
    - (2) Hydraulic studies should include estimates of scour at bridge piers and evaluation of abutment stability. Bridge foundations should be designed to withstand the effects of scour without failing for the worst conditions resulting from floods equal to or less than the 100-year flood. (See HEC 18, Chapters 3 and 4.) Bridge foundations should be checked to ensure that they will not fail due to scour resulting from the occurrence of a superflood on the order of magnitude of a 500-year flood. (See HEC 18,Chapter 3.)
    - (3) The geotechnical analysis of bridge foundations should be performed on the basis that all stream bed material in the scour prism above the total scour line for the design flood (for scour) has been removed and is not available for bearing or lateral support. In addition, the ratio of ultimate to applied loads should be greater than 1.0 for conditions of scour for the superflood. (See HEC 18, Chapter 3.)
    - (4) Data on scour at bridge piers and abutments should be collected and analyzed in order to improve existing procedures for estimating scour. (See HEC 18, Chapter 1.)
3. Existing Bridges. All existing bridges over tidal and non-tidal waterways should be evaluated for the risk of failure from scour during the occurrence of a superflood on the order of magnitude of a 500-year flood. (See HEC 18, Chapter 5.)
    - (1) An initial screening process should identify bridges susceptible to scour and establish a priority list for evaluation. (See HEC 18, Chapter 5.)

- (2) Bridge scour evaluations should be conducted for each bridge to determine whether it is scour critical. A scour critical bridge is one with abutment or pier foundations which are rated as unstable due to:
  - (a) observed scour at the bridge site or
  - (b) a scour potential as determined from a scour evaluation study. (See HEC 18, Chapter 5.)
- (3) The procedures in Chapter 5 of HEC 18 should be followed in conducting and documenting the results of scour evaluation studies

4. <u>Scour Critical Existing Bridges</u>. A plan of action should be developed for each existing bridge determined to be scour critical. (See HEC 18, Chapter 5.)
   - (1) The plan of action should include instructions regarding the type and frequency of inspections to be made at the bridge, particularly in regard to monitoring the performance and closing of the bridge, if necessary, during and after flood events. (See HEC 18, Chapter 7.)
   - (2) The plan of action should include a schedule for the timely design and construction of scour countermeasures determined to be needed for the protection of the bridge. (See HEC 18, Chapter 7.)
5. <u>Bridge Inspectors</u>. Bridge inspectors should receive appropriate training and instruction in inspecting bridges for scour. (See HEC 18, Chapter 6.)
   - (1) The bridge inspector should accurately record the present condition of the bridge and the stream. At least one cross section at each bridge should be documented and compared with previously recorded cross section(s) at the site. Pier locations and footing elevations should be included.
   - (2) The bridge inspector should identify conditions that are indicative of potential problems with scour and stream stability.
   - (3) Effective notification procedures should be available to permit the inspector to promptly communicate findings of actual or potential scour problems to others for further review and evaluation.
   - (4) Special attention should be focused on the routine inspection of scour critical bridges and on the monitoring and closing as necessary of scour critical and other bridges during and after floods.
6. <u>EXISTING POLICY AND GUIDANCE</u>. The following existing policy and guidance serve as the basis for the recommendations set forth in paragraph 4.
   - <u>AASHTO Standard Specifications for Highway Bridges</u>. The FHWA has accepted these specifications for the design of highway bridges. The 1991 Interim Specifications contain requirements for designing bridges to resist scour. Particular attention is directed to Article 1.3.2, Hydraulic Studies, which advises that, "Hydraulic studies . . . should include applicable parts of the following outline:" Included in this outline is item 1.3.2.3 (b), Estimated scour depth at piers and abutments of proposed structures.
   - <u>AASHTO Manual for Bridge Maintenance</u>. The FHWA endorses the guidance contained in this 1987 Manual for Bridge Maintenance. Particular attention is directed to the following two statements which support the recommendations contained in this Technical Advisory:

    - (1) "The primary function of the bridge maintenance program is to maintain the bridges in a condition that will provide for safe and uninterrupted traffic flows. The protection of the investment in the structure facility through well programmed repairs is second only to the safety of traffic and to the structure itself." (p. 25.)
    - (2) "Determining an effective solution to a stream bed or river problem is difficult. Settlement of foundations, local scour, bank erosion, and channel degradation are complex problems and cannot be solved by one or two prescribed methods. Hydraulic, geotechnical, and structural engineers are all needed for consultation prior to undertaking the solution of a serious maintenance problem. In some cases, certain remedial work could actually be detrimental to the structure." (p. 155.)
  - AASHTO Manual for Maintenance Inspection of Bridges. The FHWA endorses the guidance provided in the current version of this manual which serves as a standard and provides uniformity in the procedures and policies in determining the physical condition and maintenance needs of bridges. The manual emphasizes the importance of documenting and comparing cross sections taken upstream of bridges over time to discern potential scour problems.
  - Code of Federal Regulations, 23 CFR 650, Subpart C. The 1989 revision of this FHWA regulation on the National Bridge Inspection Standards requires that bridge owners maintain a bridge inspection program that includes procedures for underwater inspection. This Technical Advisory and HEC 18 provide guidance on the development and implementation of procedures for evaluating bridge scour to meet the requirements of the regulation.
  - Memorandum From the Director, Office of Engineering, to Regional Federal Highway Administrators and Direct Federal Program Administrator Dated April 17, 1987. This memorandum stated in part, "Each State should evaluate the risk of its bridges being subjected to scour damage during floods on the order of a 100 to 500 year return period or more."
  - FY 1991 High Priority Research Program of the FHWA. The FHWA recognizes the subject of scour at bridges as a long range high priority national program area for research and recommends that appropriate studies be carried out to improve the state-of-practice of designing new bridges and evaluating existing bridges for scour.

/S/ Original signed by
Thomas O. Willett, Director
Office of Engineering

APPENDIX D SAMPLE PLAN OF ACTION

New York State Department of Transportation

Plan of Action for Scour Critical Bridges

BIN 1009320

NYS Route 12 over Mill Brook

Table of Contents

New York State Department of Transportation
Plan of Action for Scour Critical Bridges

Region: Region 9 - Binghamton **County:** County 2 - Chenango **Bin:** 1009320
Feature Carried: 12 12 92021191 **Feature Crossed:** Mill Brook
Plan of Action Date: 3/12/2019 **Plan of Action updated every** 24 **Months**
Primary Owner: NYSDOT **Political Unit: 0712 –** Town of Oxford
Year Built: 1937 **AADT:** 5253 (2015)
Location: 1.7 MI SW JCT RT 12 + 220 **Over Tidal Water?** No
Abutment Foundation Type: Continuous - Spread-on-Earth Cut **Number of Spans:** 1
Pier(s) Foundation Type: N/A **Continuous over Pier?** N/A **Redundant?** Yes
Streambed Material: Glacial Till **Critical Structure?** No
NYSDOT HVA Class Score: 31 **FHWA Code (Item 113):** 3 **Source of item 113 Code:** R

Type(s) of Inspection/Monitoring Performed

Biennial Inspection? Yes **Post Flood Inspection?** Yes **Special (SILO) Inspection?** No **Interim Inspection?** No
Diving Inspection? No **Fathometer Survey?** No **Debris Prone Inspection?** Yes
Flood Event Monitoring: Moderate Risk **Scour Monitor (list type used):** N/A
Criteria for Monitoring? NYSDOT *Bridge Flood Warning Action Plan*: Flood Warning or Flash Flood Warning issued by the National Weather Service OR Flood Watch initiated by RSME, RBME or RE.

Closure Instructions

Criteria for Closure: Follow NYSDOT *Bridge Flood Warning Action Plan. General Instructions (page 6)*. If a Critical Bridge Item, item a. – g. on *General Instructions* shows change, the bridge being watched may require closure if any-one or combination of these items is met, unless there are valid reasons known that the bridge remains safe. Should you believe that the bridge is becoming unsafe for any reason, immediately close the bridge and then notify the appropriate parties. See Road Closure Plan (page 5)
Authorization for Closure: Any qualified personnel performing Flood Watch
Detour Route: Detour from Begin side of bridge to End side of bridge: 16.4 miles – 24 min**,** NY 12 S, CR 32A E, CR 32 N, Main St. W, NY 12 S., See Detour Route (page 9)
Potential Alternative Detour Route(s): NY 220, NY 8
Criteria for Re-opening Structure: Certified safe by a licensed Professional Engineer in New York State.

Countermeasures

Countermeasures Considered 1: Bridge Replacement **Cost 1:** $1.4M
Countermeasures Considered 2: Stone scour protection **Cost 2:** $124,165 (page 11)

Countermeasures Considered 3: Sheeting **Cost 3:** $337,217 (page 11)
Countermeasures Considered 4: Pile Retrofit **Cost 2:** $2.8M (page 11)
Countermeasures Recommended: Stone scour protection **Status:** Under design
Countermeasures Installed: N/A **Date Installed:**
Bridge Scheduled for Replacement? No **Estimated Letting Date:** N/A

Bridges/Culverts on Detour Route

Detour Route: NY 12 S, CR 32A, CR 32 N, Main St. W

BIN/CIN Number	Feature Carried	Feature Crossed	Load Posted
1009310	12 12 92021168	Bowman Creek	No
1041740	Main St.	Chenango River	No
3350540	County Route 32	Glen Rd. Brook	No
3350570	County Route 32	Farrel Creek	No
3350580	County Route 32	Bear Brook	No
3350590	County Route 32	Eddy Brook	No
C920054	12 12 92021201	Unknown stream	No
C920053	12 12 92021199	Unknown stream	No
C920052	12 12 92021197	Unknown stream	No

Authorization

Author(s) of POA: John Doe **Date Signed:** 3/12/2019
Checked By: Mavis Bitten, PE **Date Checked:** 3/12/2019

Road Closure Plan

CLOSURE OF A BRIDGE OR STRUCTURE

Close a bridge or structure to traffic if it is unsafe, if it is becoming unsafe, or if any observation causes the structural integrity of the structure to be questioned.

References:
NYSDOT Bridge Flood Warning Action Plan Step #9 (page 8)
NYSDOT Bridge Flood Warning Action Plan Bridge Flood Warning Rprt & Instructions (pgs 12-13) NYSDOT Bridge Flood Warning Action Plan Culvert Flood Warning Rprt & Instructions (pgs 18-19) NYSDOT Bridge Inspection Manual (2017) Appendix A, UCBI §165.12 (page 222)
NYSDOT Bridge Inspection Manual (2017) Appendix B, Flagging Procedure, §I 3rd (page 225)
NYSDOT Bridge Inspection Manual (2017) Appendix B, Flagging Procedure, §VIII (page 234)

Closure of a bridge needs notification & coordination (RD, DCES, RDO, RE, RBME, RSME, RTE, REM, RCE, RDE, RSE, RHE, 911).

References:
NYSDOT Bridge Flood Warning Action Plan Step #11 (page 8)
NYSDOT Bridge Inspection Manual (2017) Appendix B, Flagging Procedure, §III (top of page 228) MAP 7.9-11 Closing or Posting of State-Owned Bridges and Culverts

If a bridge needs immediate closure to assure public safety, that shall take precedence prior to initiating notifications beyond what's needed for closure.

Reference:
NYSDOT Bridge Inspection Manual (2017) Appendix B, Flagging Procedure, §III (top of page 228)

In an extreme case, where an actual failure or clearly perilous condition exists, take immediate measures to close the bridge and close the feature under the bridge.

Reference:
NYSDOT Bridge Inspection Manual (2017) Appendix B, Flagging Procedure, §III.A.2 (page 228)

GENERAL INSTRUCTIONS

Visually inspect bridge, stream and approach roadway each time the bridge is visited if on a roving patrol or about every half-hour if stationed at the bridge. When the water is above the critical freeboard elevation, a stationary watch at the bridge must be established. For those items inspected, circle the appropriate response. If not inspected, leave blank. Circle N for no, none or no change in condition since beginning of flood watch. Circle Y for yes if a change has occurred. A "yes" response requires a written explanation of what was observed or changed. Record under freeboard the Estimated, Measured, Gage readings and circle E, M, or G as appropriate. Inspections should include but not be limited to the upstream and downstream sides of the bridge, the upstream and downstream sides of the channel near the bridge and the approach roadways to the bridge. A "yes" response for Critical items requires the bridge to be closed unless there are valid reasons known that the bridge remains safe. Should you believe that the bridge is becoming unsafe for any reason, immediately close the bridge and then notify the Resident Engineer and

LINE ITEM DESCRIPTION:

TIME – Military Time

BRIDGE

a. Alignment- Sight along fascia, railing, curb, paint stripping, etc... for horizontal discontinuity or misalignment. Record the amount of misalignment between spans.

b. Profile- Sight along fascia, railing, curb, paint striping, etc... for vertical discontinuity or misalignment. Record the amount of misalignment between spans.

e. Vibration- When there is no traffic on the bridge, check each span for vibration or swaying motion due to stream flow.

f. Noise- When there is not traffic on the bridge, listen for creaks, groans, snapping, cracking, scraping or popping noises coming from the bridge.

g. Freeboard- Measure the distance from the lowest point on the bottom of the bridge superstructure to the water surface to the nearest half foot. If the water level is above the bottom

HIGHWAY

a. Erosion- Check approach roadways, embankment slopes, shoulders, and pavement for erosion. Extend limits of inspection to cover roadways parallel to stream

b. Settlement- Check items listed under Erosion for settlement.

c. Cracking- Note any new cracks in times listed under Erosion

STREAM

a. Debris Flow- Record the quantity of ice, brush, trees, logs, etc... carried in the stream as "N" for none, "L" for light, "M" for medium, and "H" for heavy

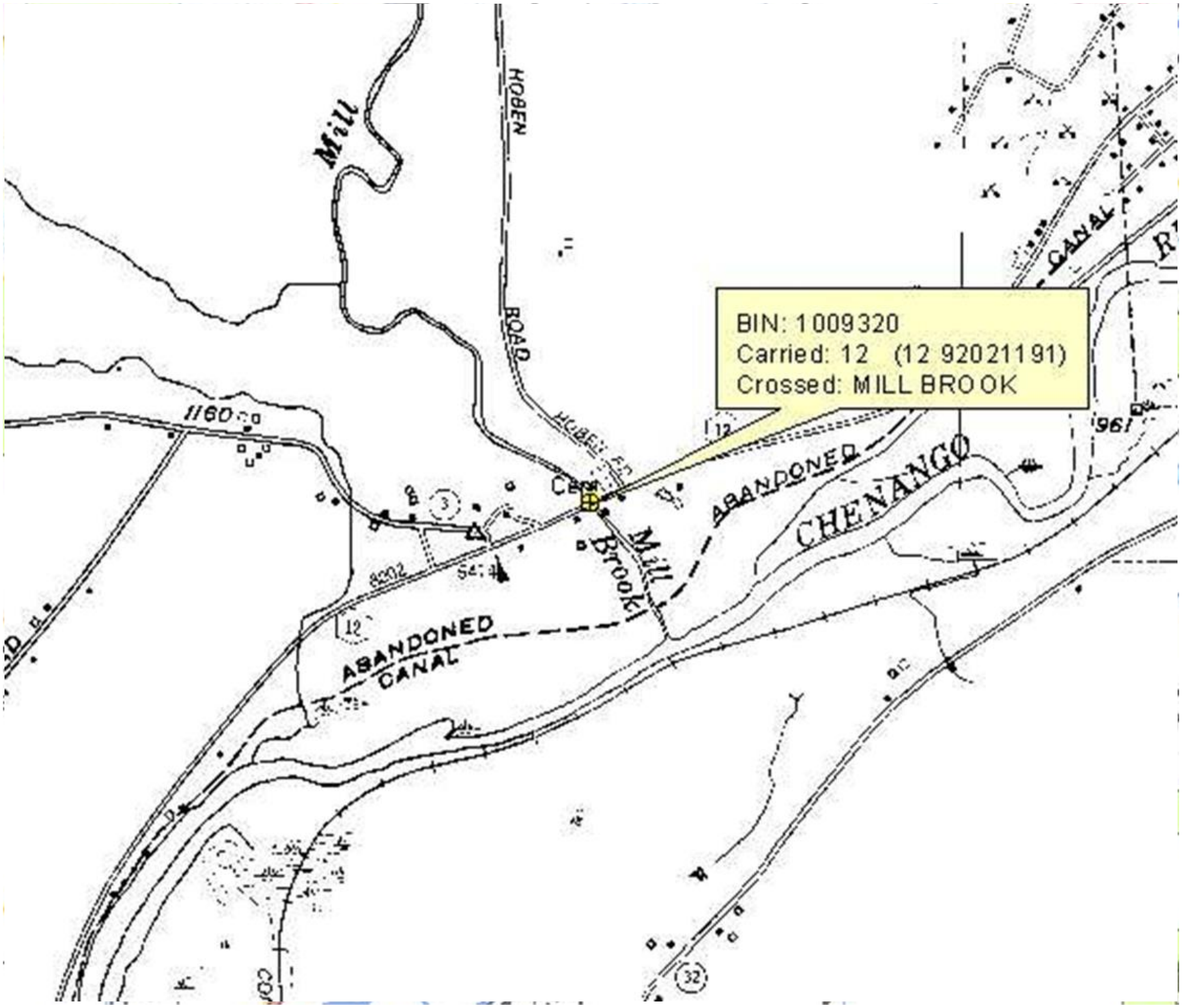
b. Impacting Debris- Is any debris or ice hitting the superstructure?

c. Snagging Debris- Is any debris or ice caught or snagged on the superstructure, substructures or along the stream channel? Note in the Remarks section where the debris is snagging.

d. Flow Characteristics- Have the flow characteristics of the stream changed? (i.e. location of eddys, strength and direction of currents, location of standing waves, location of boils, etc...)

e. Erosion- Is there any observed erosion occurring along stream banks, stream bottoms, or

f. Noise- Can you hear stones or other objects rolling or sliding along the stream bed?

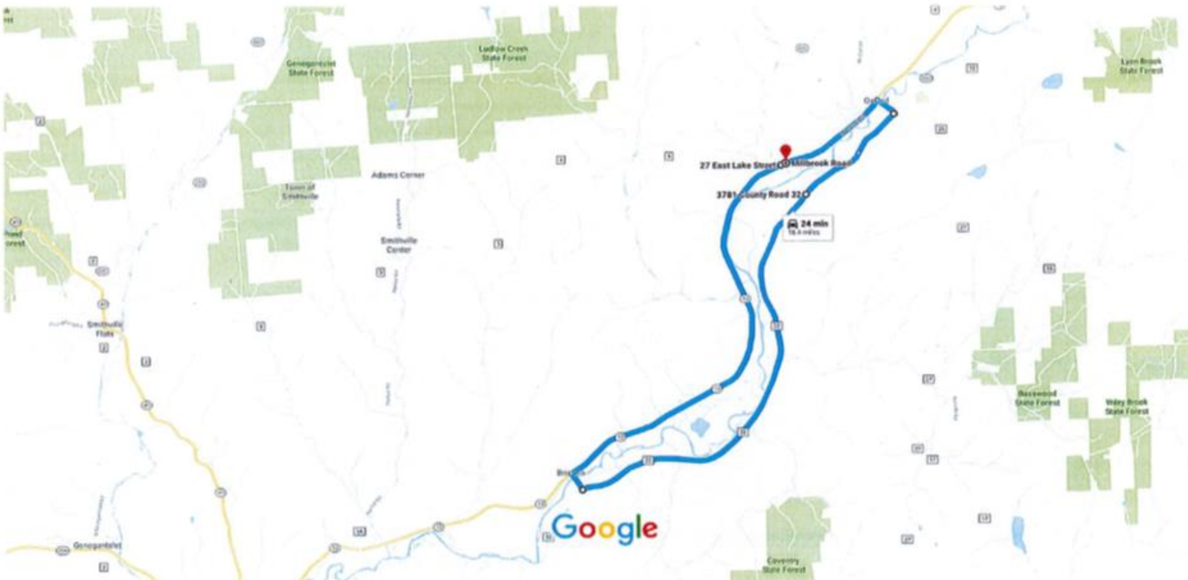

BIN: 1009320
Carried: 12 (12 92021191)
Crossed: MILL BROOK
Mill
HOBEN
ROAD
HOBEN RD
Mill
Brook
ABANDONED
CANAL
ABANDONED
CHENANGO
CANAL
1160
961
547

Google Maps

27 E Lake St, Oxford, NY 13830 to Millbrook Rd, Oxford, NY 13830

Drive 16.4 miles, 24 min

NY 12 over Mill Brrok detour when BIN 1009320 is closed



Map data ©2019 Google 1 mi

27 E Lake St

Oxford, NY 13830

↑ 1. Head southwest on NY-12 S toward County Rd 3

6.2 mi

↰ 2. Turn left onto Cort 32C

0.3 mi

↰ 3. Turn left onto E River Rd

6.3 mi

17 min (12.8 mi)

3781 County Rd 32

Oxford, NY 13830

↑ 4. Head northeast on E River Rd

1.0 mi

↑ 5. Continue onto Greene St

0.8 mi

6. Turn left onto Main St

230 ft

7. Turn left to stay on Main St

0.3 mi

8. Turn left onto NY-12 S/N Canal St
   Continue to follow NY-12 S

1.6 mi

9. Turn right onto Millbrook Rd

23 ft

7 min (3.6 mi)

Millbrook Rd

Oxford, NY 13830

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

APPENDIX E BRIDGE FLOOD WARNING ACTION PLAN

2022

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
BRIDGE FLOOD WARNING ACTION PLAN
FOR STATE OWNED BRIDGES &
BRIDGE SIZE METAL CULVERTS

I. INTRODUCTION

This plan establishes procedures for monitoring State Owned or Maintained Bridges and Bridge Size Metal Culverts. Large Culverts can be included at the discretion of the regions. The Bridge Flood Warning Action Plan (BFWAP) was originally implemented in 1995 and covered only bridges. In 2007, a Bridge Sized Metal Culvert Memo was added to this plan. Guidance from the 2007 memo has been included throughout this document and is no longer a supplement memo in this document.

Monitoring should begin during periods of "Flood Warnings" or “Flash Flood Warnings” as reported by the National Weather Service and/or New York State Emergency Management Office (SEMO). It shall be the policy of the New York State Department of Transportation to follow these procedures to ensure the safety of the State Owned and/or Maintained structures during the periods of "Flood Warning" or “Flash Flood Warnings”. Bridges and Bridge Size Metal Culverts covered by this plan are divided into two groups: "High Flood-Risk and Moderate Flood-Risk".

II. GUIDANCE

During a flood event, all structures included on the Flood-Watch List and identified as "High Flood-Risk” or “Moderate Flood-Risk” are initially monitored on an intermittent basis until a Critical Condition is observed. When a “Critical Condition” is observed any Bridge(s) or Bridge Sized Metal Culvert(s) shall be monitored continuously.

During any Flood-Watch patrol, crews shall monitor Critical Conditions and Critical Items. Critical Items is a predetermined list of items set forth in this document (see below). Crews shall complete the NYSDOT Bridge Flood Warning Report or NYSDOT Metal Culvert Flood Warning Report (Form 6.1 included in the Hydraulic Vulnerability Manual).

A Critical Condition is an elevation set by the Regional Hydraulics Engineer that triggers a full-time watch and differs from Critical Items. When flood waters reach the predetermined elevation (Critical Condition), the bridge will be watched full-time. Critical Conditions can be marked with delineators, board gages or any other device that can be easily seen from a safe distance. Additionally, any bridge can become a full-time watch or require an immediate closure if a Critical Item is observed and determined to be grounds for an immediate closure. Critical Items are as follows:

Bridge – Critical Items

- Alignment
- Profile
- Length
- Vibration
- Noise
- Freeboard

Bridge Size Metal Culvert – Critical Items

- Pipping
- Plugged
- Pavement Deformation
- Overtopping
- Settling
- Cracking

III. SELECTION CRITERIA

It is assumed that Bridges and Bridge Size Metal Culverts have already been placed on the Flood-Watch list based on procedures in Section 3 & 6 of this manual. Prior to the implementation of the Culvert Vulnerability in 2007 (now Section 3.4) the criteria below were used to determine if a Bridge Size Metal Culvert was added to the Flood-Watch List and Post-Flood Inspection List. With this updated manual, Bridges and Bridge Sized Metal Culverts are now selected based on guidance in Section 3 & 6 of this Manual.

Guidance from the 2007 Culvert Memo was as follows:

If any of the following conditions exist on a Bridge Size Metal Culvert, the structure should be added to the Flood-Watch List.

Primary Member >= 3
Beginning Abutment Erosion >=3 Ending Abutment Erosion >=3 Pier Erosion Rating >=3
Stream Alignment >=3
Waterway Opening >=3
Channel Erosion >=3

Large Culverts:
All Multiple Pipe Culverts with maximum individual span >=20.
Metal Plate (Pipe) Arch with Abutment Recommendation of 8, with maximum individual span >=20. This is due to some metal pipe culverts with corrugated inverts being coded as Arch. Large culverts with concrete inverts do not need to be included unless one of the other criteria above is met.

Furthermore, if any of the following conditions exist, the bridge would be added to the Post-Flood Inspection List.

Primary Member >= 3
Beginning Abutment Erosion >=4 Ending Abutment Erosion >=4 Pier Erosion Rating >=4
Stream Alignment >=4
Waterway Opening >=4
Channel Erosion >=4

Large Culverts:
All Multiple Pipe Culverts with maximum individual span >=20.
Metal Plate (Pipe) Arch with Abutment Recommendation of 8, with maximum individual span >=20. This is due to some metal pipe culverts with corrugated inverts being coded as Arch. Large culverts with concrete inverts do not need to be included unless one of the other criteria above is met.

IV. RESPONSIBILITIES FOR THE PROCEDURES

Primary Procedural Responsibility

The Structures Management Unit and Office of Operations in each NYSDOT Region shall be primarily responsible for interpretation and for maintenance of these procedures.

Organizational Responsibility

The following Offices in the Department of Transportation Regions shall have the organizational responsibility for following the procedures as outlined in this plan:

OFFICE of OPERATIONS:
- Transportation Maintenance Division
- Traffic and Safety Division (as referenced in M.A.P. 7.9-11)

OFFICE of ENGINEERING DIVISION:
- Structures Design and Construction Division

REGIONAL OFFICES:
- Regional Directors Office
- Regional Director of Operations
- Regional Design Engineer
- Regional Bridge Maintenance Engineer
- Regional Structures Management Engineer
- Regional Hydraulics Engineer

VI. DEFINITIONS

Bridge - a structure including supports erected over a depression or an obstruction such as water, highway, or railway, having a track or passageway for carrying public highway traffic and having an opening measured along the center of the roadway of more than twenty feet between under copings of abutments or spring lines or arches, or extreme ends of openings for multiple boxes and may include multiple pipes where the clear distance between openings is less than half of the smaller contiguous opening. The term bridge, as defined in this Part, shall also include the approach spans.

Bridge Size Metal Culverts - All Multiple Metal (Pipe) Culverts or Metal Plate (Pipe) Arch with maximum individual span >20.

Large Culvert - is typically a hydraulic structure passing through embankment, where the minimum depth of fill is typically greater than 2 feet with an opening: measured perpendicular to its skew that is greater than or equal to 5 feet and measured along the centerline of the roadway that is less than or equal to 20 feet including multiple pipe structures where the clear distance between pipes is less than half of the smaller pipe diameter.

State Bridge - A structure meeting the definition of a bridge and carrying highway traffic for which the New York State Department of Transportation has any maintenance or ownership responsibility. During construction, temporary structures erected under Item 619.06 are the responsibility of the Contractor and are not covered by this plan. Temporary structures belonging to the Department, which are not part of an existing contract, may be placed on the Flood-Watch List at the discretion of the Regional Structures/Structures Management Engineer.

Non-State Bridge - Any structure carrying traffic meeting the definition of a bridge for which the New York State Department of Transportation has no maintenance or ownership responsibility.

Flood Warning or Flash Flood Warning - An official notification from the National Weather Service or from the State Emergency Management Office (SEMO) that specifies that a flood warning or a flash flood warning is in effect for a geographic area. This notification activates the bridge monitoring procedures outlined in this document.

Flood-Watch List - The list of structures that requires monitoring as described in this plan. This list shall be maintained by the Structures Management Unit.

Flood-Watch Training - All Flood-Watch Personnel should be trained in administering the Bridge Flood-Watch Process. Training will be provided by the Regional Structures Management Unit.

VII. NOTIFICATION OF FLOOD WARNING

Flood Warnings or Flash Flood Warnings issued by the National Weather Service are transmitted electronically via iNWS alerts or NY Alerts directly, to the Regional Director of Operations (RDO) and/or his designee, the Regional Traffic Operations Center, (RTOC), the Regional Bridge Maintenance Engineer (RBME), Regional Hydraulics Engineer (RHE) and the Regional Structures Management Engineer (RSME).

Occasionally, Flood Warnings or Flash Flood Warnings notification originates from the Residencies or Local Emergency Management Officials. In this case, the (RDO), RTOC, (RBME), (RHE) and the (RSME) should be notified. A Local Flood Warning or Flash Flood Warning can also be declared by the Regional Structures Management Engineer or the Regional Bridge Maintenance Engineer.

The Regional Bridge Maintenance Engineer shall, upon receiving notification of a Flood Warning or Flash Flood Warning, monitor the bridges under their responsibility using appropriate numbers of trained personnel.

VIII. TERMINATION OF BRIDGE MONITORING:

Monitoring shall continue until termination of the Flood Warning or Flash Flood Warning by the National Weather Service and/or the Regional Bridge Maintenance Engineer (RBME) or Regional Structures Management Engineer (RSME) has determined that monitoring is no longer necessary. In some cases, the RBME or RSME may determine that monitoring is no longer necessary without official cancellation of a Flood Warning or Flash Flood Warning from the National Weather Service.

IX. DOCUMENTATION OF BRIDGE MONITORING:

The Regional Bridge Maintenance Engineer shall transmit relevant transcripts of verbal reports and copies of the Bridge Flood Warning Report(s) or the Metal Culvert Flood Warning Report(s) from flood monitoring activities to the Regional

Structures Management Unit Copies of these reports and correspondence will allow the Regional Hydraulics Engineer to fine tune the Flood-Watch List, Critical Conditions and determine if a Post-Flood Inspection is needed. The Regional Hydraulics Engineer shall file "bridge specific" flood activity information (individual bridge inspection reports, flag bridge reports, etc.), in the appropriate file location with a copy of the report(s) entered into the Bridge Data Information System (BDIS).

X. ORGANIZATIONAL RESPONSIBILITIES FOR PROCEDURAL STEPS:

RESPONSIBILITY		ACTION
Regional Hydraulics Engineer	1.	Upon implementation of this procedure, prepares and maintains a list of Flood-Watch Bridges. This list will be titled "Flood-Watch List ". This list will contain the current bridge condition rating, the bridge geographic location. This list shall be developed based on criteria set forth in Section 6 of the New York State Hydraulic Vulnerability Manual. Provides the Regional Director of Operations with a current copy of the "Flood-Watch List ".
Regional Director of Operations	2.	Determines the personnel that will be responsible for monitoring the bridges on the Regional "Flood-Watch List". Distributes any updated list to the Regional Bridge Maintenance Engineer.
Regional Bridge Maintenance Engineer	3.	Reviews the bridges on his/her copy of the "Flood-Watch List", and determines staffing requirements for various Flood Warning or Flash Warning scenarios. Ensures that Flood Watch personnel receive "Bridge Flood-Watch Training".
Regional Director of Operations Or	4.	Receives official notification of a "Flood Warning" or "Flash Flood Warning". Notification should include:

The RTOC Or Any other Designee		a). description of the anticipated flood and anticipated flood intensity, b). geographic area to which the flood warning applies, and c). anticipated duration of flood.
	5.	Records the above information and a). The time and date of the notification b). Name of the party providing the notification.
	6.	Immediately notifies the Regional Bridge Maintenance Engineer in the "Flood Warning" or “Flash Flood Warning” effected areas and transmits the descriptive "Flood Warning" or “Flash Flood Warning information.
	7.	Notifies the Regional Structures Management Engineer that a Flood Warning or Flash Flood Warning notification has been received and that the "Bridge Flood Warning Action Plan" is to be initiated. Descriptive information received, such as anticipated intensity, duration, and geographic area shall be included in the notification. If the RTOC receives the initial Flood Warning or Flash Flood Warning notification, then that RTOC shall promptly notify the Director of Operations or his/her designee.
Regional Bridge Maintenance Engineer	8.	Initiates the "Bridge Flood Warning Action Plan”. a). Refers to the "Flood-Watch List" and identifies the Bridge in the geographical areas of the Flood Warning or Flash Flood Warning, b). Makes a preliminary assessment of the number of two-person teams required to cover all of the bridges on a continuing watch basis.

c). <u>calls into service</u> the estimated number of field crews required to implement the "Bridge Flood Warning Action Plan" and establishes an appropriate communication network.

d). <u>Evaluates</u> the initial number of crews called into service and makes personnel "call in" adjustments as necessary. The Regional Bridge Maintenance Engineer <u>shall request assistance</u> from the Director of Operations to provide additional personnel, if needed, from other Bridge Maintenance crews, other Residencies, or other functional areas. If necessary, the Regional Bridge Maintenance Engineer can dispatch one-person teams to bridge sites temporarily, to assure coverage for the duration of the flood event.

Each team shall be equipped with appropriate personal safety equipment, a cell phone or other appropriate communication equipment, etc. Crews shall also be equipped with traffic control devices such as flags and traffic cones. Barricades necessary to close a bridge must be made available on call.

Bridge Flood Warning Field Team

9. In monitoring a Bridge, the Bridge Flood Warning Field Team <u>shall look for signs</u> of <u>direct physical damage, signs of imminent or actual movement</u>, of the pavement over the structure, the structure is under pressure flow or overtopping, etc. If the field team makes **any** observation which causes them to question the structural integrity of the bridge, the field team shall **immediately close the bridge** to all traffic and immediately notify the Regional

Bridge Maintenance Engineer. During normal duty hours, the field team may contact the Regional Bridge Maintenance Engineer for approval before closing the bridge.

10. Each Bridge Flood Warning Field Team shall maintain a continual diary of their activities and observations for the duration of their flood monitoring assignment by completing the Bridge Flood Warning Report or Metal Culvert Flood Warning Report. Each report has detailed directions of what to look for.

Regional Bridge Maintenance Engineer
or
any other Management Personnel

11. Upon receiving notification from a field team that a bridge is being closed, immediately begins notification proceedings and actions for closing bridges as described in M.A.P. 7.9-11 "Closing and Posting of State-Owned Bridges".

12. When the Flood Warning or Flash Flood Warning is cancelled, discontinues the Flood Warning Action Plan and recalls the Bridge Flood Warning Field Teams. Bridges may continue to be monitored if local conditions warrant.

13. Upon completion of all flood warning or Flash Flood Warning monitoring activities, forwards copies of all "Bridge Specific Information" to the Regional Hydraulics Engineer and the Regional Director of Operations. "Bridge Specific Information" would include all transmittals, letters or memoranda specifically highlighting any flood damage, need for repairs, need for further evaluations, etc. Transmits a copy of Bridge Flood Warning Report or Metal Culvert Flood Warning Report to the Regional

Hydraulics Engineer. This will allow for revisions to the "Flood-Watch Lists" and determine if a Post-Flood Inspections is needed

Regional Hydraulics Engineer shall retain the Bridge Flood Warning Report and Metal Culvert Flood Warning Report in a local file location.

Regional Hydraulics Engineer

14. Document by memo or letter, all verbal notifications and other noteworthy verbal communications resulting from the Bridge Flood Warning Action Plan. A copy of all such documentation shall be retained in the local folder for future reference.

15. After flooding has subsided, arranges for Post-Flood Inspections. Any State bridge closed, as a result of this procedure must also be re-inspected and certified as safe, by a licensed New York State engineer, prior to reopening it, as specified in Appendix A - Section 165.12 of the Uniform Code of Bridge Inspection.

Recommends to the Regional Director of Operations, Regional Structures Engineer, Regional Bridge Maintenance Engineer and Regional Structures Management Engineer that a bridge has been certified as safe and can be reopened.

16. Reviews documentation received from completed Bridge Flood Warning Reports or Metal Culvert Flood Warning Reports to see if any revisions to the Flood-Watch List are warranted and modifies and redistributes the updated list accordingly.

Director of Operations	17.	Upon receiving certification and Regional Director concurrence that a Bridge closed during the flood can be reopened, reopen the Bridge and notifies appropriate Department and public officials as described in M.A.P. 7.9-11.

APPENDIX F NBI ITEM 60 – SUBSTRUCTURE

Item 60 – Substructure:

This item describes the physical condition of piers, abutments, piles, fenders, footings, or other components. Rate and code the condition in accordance with the previously described general condition ratings. Code N for all culverts.

All substructure elements should be inspected for visible signs of distress including evidence of cracking, section loss, settlement, misalignment, scour, collision damage, and corrosion. The rating given by Item 113 - Scour Critical Bridges, may have a significant effect on Item 60 if scour has substantially affected the overall condition of the substructure.

The substructure condition rating shall be made independent of the deck and superstructure.

Integral abutment wingwalls to the first construction or expansion joint shall be included in the evaluation. For non-integral superstructure and substructure units, the substructure shall be considered as the portion below the bearings. For structures where the substructure and superstructure are integral, the substructure shall be considered as the portion below the superstructure.